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DESTRUCTIVE
AND
USEFUL INSECTS

THEIR HABITS AND CONTROL

BY

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AND

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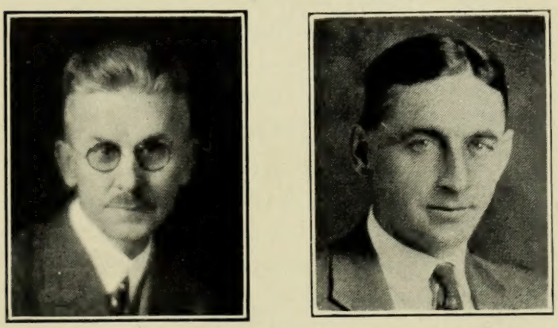

Left—C. L. METCALF, Professor of Entomology, University of Illinois.
Right—W. P. FLINT, Chief Entomologist, Illinois State Natural History Survey.

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TO

STEPHEN ALFRED FORBES

Dean of American Economic Entomologists

AND

HERBERT OSBORN

Master Teacher of Entomologists

THIS BOOK IS AFFECTIONATELY DEDICATED

PREFACE

This book is intended as a text for the beginning student in entomology and also as a guide or reference book for practical farmers, gardeners, fruit growers, farm advisers, physicians, and general readers who desire up-to-date and reliable information about the many kinds of insect pests. It is the outgrowth of twenty-five years of practical entomological work in combating destructive insects, on the part of one of the authors; and fifteen years' experience in teaching large classes of university students of entomology, by the other author. It aims to present what the authors believe to be the essentials of economic entomology, in language which any reader can understand.

As a textbook, it is adapted to the two types of introductory courses commonly given in American universities and colleges. In the first ten chapters, enough of the fundamentals of technical entomology is given to serve as a basis for further special study in the subject or for students of biology who desire an introduction to entomology. The later chapters of the book are devoted to an analysis of the more important insect pests of the major crops in the continental United States and southern Canada. It is hoped that these discussions will be a ready reference for the practical worker who wishes to determine particular pests and learn their control; and serve classes seeking a broad course in applied entomology, as a part of an agricultural education. Material enough is available so that, by selection on the part of the teacher, practical courses adapted to the needs of a great variety of special classes, or different sections of the country, may be given.

A table or key to help the student or practical worker to identify a particular pest, when the plant or animal attacked is known, introduces each chapter in the latter part of the book. In the discussion of the several pests, a uniform system has been followed: first, the recognition marks and type of injury; second, a brief statement of the life history, with descriptions of the stages and significant habits; third, the control measures known or believed to be practical; and fourth, a few references, which may serve in part to acknowledge our indebtedness to our many colleagues in entomological work and also to point the reader to more extensive sources of information. In giving control measures we have rigorously selected only those which appear to have been tried and proved effective. On account of the limitations of space, the natural enemies of the various species are discussed only where they have been of especial significance in control. In discussing the life cycle, the overwintering

stage forms the starting point in all cases. Unless otherwise stated the dates given are based on observations in central Illinois.

In an endeavor to avoid as many errors as possible, the authors have submitted the several chapters of manuscript to authorities in their special fields. We desire to thank the following persons for their invaluable aid in criticising parts of the book and in furnishing illustrations. A. J. Ackerman, George Ainslie, E. A. Back, W. V. Balduf, J. H. Bigger, F. C. Bishopp, Fred E. Brooks, A. F. Burgess, D. J. Caffrey, B. R. Coad, C. C. Compton, R. A. Cooley, J. J. Davis, George A. Dean, J. E. Dudley, E. O. Essig, F. A. Fenton, C. L. Fluke, T. H. Frison, B. B. Fulton, Hugh Glasgow, R. D. Glasgow, P. A. Glenn, J. E. Graf, Fay Guyton, Leonard Haseman, W. P. Hayes, W. B. Herms, J. S. Houser, Neale F. Howard, J. A. Hyslop, M. C. Lane, W. H. Larrimer, Philip Luginbill, A. E. MacGregor, S. Marcovitch, J. W. McCulloch, Z. P. Metcalf, Herbert Osborn, T. H. Parks, P. J. Parrott, Edith M. Patch, Antonio M. Paterno, Alva Peterson, R. H. Pettit, W. J. Phillips, B. A. Porter, H. J. Quayle, George I. Reeves, G. A. Runner, H. H. Severin, Franklin Sherman, Loren B. Smith, J. R. Watson, R. L. Webster, C. A. Weigel, V. L. Wildermuth, and H. N. Worthley.

Grateful acknowledgment for the illustrations is made in connection with each figure.

The authors will be grateful to any readers who will advise them of errors or criticisms that come to their attention.

C. L. Metcalf.
W. P. Flint.

Urbana, Illinois
August, 1928.

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DESTRUCTIVE AND USEFUL INSECTS

CHAPTER I

INSECTS AS ENEMIES OF MAN

The struggle between man and insects began long before the dawn of civilization, has continued without cessation to the present time, and will continue, no doubt, as long as the human race endures. It is due to the fact that both men and certain insect species constantly want the same things at the same time. Its intensity is owing to the vital importance to both, of the things they struggle for, and its long continuance is due to the fact that the contestants are so equally matched. We commonly think of ourselves as the lords and conquerors of nature, but insects had thoroughly mastered the world and taken full possession of it long before man began the attempt. They had, consequently, all the advantage of a possession of the field when the contest began, and they have disputed every step of our invasion of their original domain so persistently and so successfully that we can even yet scarcely flatter ourselves that we have gained any very important advantage over them. Here and there a truce has been declared, a treaty made, and even a partnership established, advantageous to both parties of the contract—as with the bees and silkworms, for example; but wherever their interests and ours are diametrically opposed, the war still goes on and on and neither side can claim a final victory. If they want our crops they still help themselves to them. If they wish the blood of our domestic animals, they pump it out of the veins of our cattle and our horses at their leisure and under our very eyes. If they choose to take up their abode with us we can not wholly keep them out of the houses we live in. We can not even protect our very persons from their annoying and pestiferous attacks, and since the world began we have never yet exterminated—we probably never shall exterminate—so much as a single insect species. They have in fact, inflicted upon us for ages the most serious evils without our even knowing it.[1]

It is difficult to understand the long-time comparative indifference of the human species to the insect danger . . . Men and nations have always struggled among themselves. But . . . there is a war, not among human beings, but between all humanity and certain forces that are arrayed against it. Man . . . has subdued or turned to his own use nearly all kinds of living creatures. There are still remaining, however, the bacteria and protozoa that cause disease and the enormous forces of injurious insects which attack him from every point and which constitute today his greatest rivals in the control of nature.

[1] Forbes: "*The Insect, the Farmer, the Teacher, the Citizen, and the State.*"

. . . If human beings are to continue to exist, they must first gain mastery over insects . . . Insects in this country continually nullify the labor of one million men. Insects are better equipped to occupy the earth than are humans, having been on the earth for fifty million years, while the human race is but five hundred thousand years old.[1]

To some readers who have neither experienced, nor witnessed, any great injury by insects, these statements may sound extreme. Most of us, however, have learned to appreciate the potentialities for destruction of at least a few kinds of insects when we have seen army worms completely devour a field of corn, or scale insects destroy an orchard, or weevils consume and pollute a bin of grain, or clothes moths ruin valuable garments. Few, who have not studied the matter carefully, will have any idea how many and how varied are the ways in which these minute creatures injuriously affect us.

THE WAYS IN WHICH INSECTS ARE INJURIOUS TO MAN

A. They injure all kinds of growing crops and other valuable plants:

1. By chewing the foliage, stem, bark or fruit of the plant.
2. By sucking the sap of the plant.
3. By boring or tunneling in fruits, stems or leaves (internal insects).
4. By attacking the roots or underground stems (subterranean insects).
5. By laying their eggs in some part of the plant.
6. By using parts of the plant for the construction of nests or shelters.
7. By carrying other insects to the plant and establishing them there.
8. By carrying the organisms of plant diseases (fungi, bacteria, and protozoa) and injecting them into the tissues of the plant, or making wounds through which such disease organisms may gain entrance.

B. They attack and annoy man and other living animals:

1. By flying about or crawling over the animals; by laying eggs on their bodies; by entering the eyes, ears, alimentary canal or nostrils; by the repulsive odors or bad tastes of their bodies or their secretions in foods or on tableware; by the decomposition of their dead bodies.
2. By their venoms which may be injected into the body of their victim by a stinger, by the mouth parts, or by nettling hairs; or introduced when the insect is eaten or accidentally swallowed; or applied to the skin as a caustic or corrosive fluid.
3. By living on or in the body as external or internal parasites.
4. By carrying other parasites (disease germs, bacteria, protozoa, parasitic worms) on or in their bodies and infecting man or his domesticated animals with them.
5. By serving as essential hosts for the causal organisms of certain diseases which, without the insect, could not continue to exist.

C. They destroy or depreciate the value of stored products and possessions including food, clothing, drugs, animal and plant collections, paper, books, furniture, bridges, buildings, mine timbers, telephone poles, telegraph lines, railroad ties, trestles, etc.:

1. By devouring these things as their food.
2. By contaminating them with their secretions, their excretions, their eggs or their own bodies, even though the product may not be eaten.
3. By seeking protection or building tunnels or nests within or on these substances.
4. By increasing the labor and expense of packing, preserving, and sorting foods.

[1] HOWARD: "*The War against Insects,*" and other writings.

A. INSECT INJURY TO GROWING PLANTS

Nearly all the injury that insects do, results directly or indirectly from their attempts to secure food. They are undoubtedly man's chief rival for the available food supply of the world. When an insect desires as its food something that man also desires, it becomes his enemy, and we say it is an injurious insect. Because of the great numbers of insects and their unequalled variety we find that there are one or more species adapted to take as food, apparently every kind of organic material in the world—plant or animal, living or dead, dry or decomposing, raw or manufactured, sweet or sour, hard or soft.

Injury by Chewing Insects

Insects take their food in a variety of ways. A primitive method is by chewing off the external parts of a plant, grinding them up, and

Fig. 1.—Two heads of cabbage from adjoining plats. *A*, sprayed to protect it from insects; *B*, not sprayed and badly injured by chewing insects. (*From Wilson and Gentner*, in *Jour. Econ. Entomol.*)

swallowing them, solids and liquid parts together, very much as a cow or a horse grazes, though, of course, taking infinitely smaller bites. Such insects we call *chewing insects* (see Fig. 61, p. 111). No one can fail to see examples of this injury (Fig. 1). Perhaps the best way to gain an idea of its prevalence is to seek to find leaves of plants absolutely perfect in their freedom from such attack. Cabbage worms, army worms (Fig. 61, *K*), grasshoppers (Fig. 61, *C*), the Colorado potato

beetle (Fig. 61, *J*), the pear slug (Fig. 61, *H*) and the canker worm are common examples causing injury by chewing. The common, familiar Colorado potato beetles find nearly every potato patch east of the Rocky Mountains every year and, unless checked by poison, may soon strip the leaves from the plants and make the carefully planted and cultivated crop a total failure. Grasshoppers have periodically overwhelmed American farmers from the earliest pioneer days down to the present. In 1923, these insects completely destroyed the crops in one area in Montana larger than an average state in the East. Cooley says:

> Several counties near the Canadian boundary were completely denuded. Many train loads of livestock were shipped out of this territory because of actual lack of forage to keep them alive. Numerous farmers lost everything and moved out. In 1922, the farmers of this state used more than 5,500 tons of poisoned bran mash to destroy the grasshoppers.

Almost the same situation has prevailed in many states and in other years. For example, in 1919, 39 counties in Kansas used 4,565 tons, or 183 carloads, of bran, 83 tons of white arsenic, 83,000 gallons of molasses and 498,000 lemons in quelling the severe outbreak of grasshoppers in that state. In 1920, the Canadian entomologists directed the treatment of more than 1,400,000 acres of wheat in Saskatchewan with the saving of $20,000,000 worth of grain, otherwise certain to have been destroyed. Paying a bounty for dead grasshoppers at the rate of 60 cents a bushel, one county in Utah paid out more than $5,000 in a single year, accounting in this way for 274 tons of grasshoppers averaging about 8,000,000 hoppers to the ton.

Army worms, like grasshoppers, appear in countless numbers in certain years and practically devastate large areas of the country. Notable outbreaks of this kind have occurred in 1743, 1861, 1896, 1914, and 1924. The numbers of caterpillars that occur in such outbreaks can hardly be overestimated. Whole fields in which a man could scarcely put his foot to the ground without covering ten or a dozen worms are commonly observed. Since these insects feed chiefly at night, they may, unless noticed in the early stages of the outbreak, destroy a farmer's entire crop before he has time to apply control measures.

Injury by Piercing-sucking Insects

A second very important way in which insects feed on growing plants is by piercing the epidermis and sucking out the sap from the cells within. In this case, only internal and liquid portions of the plant are swallowed, although the insect itself remains externally on the plant. Such insects we call *piercing-sucking insects.* Their work is accomplished by means of an extremely slender and sharp-pointed portion of the

beak which is thrust into the plant and through which the sap is sucked. This results in a very different looking, but none the less severe, injury. The hole made by the beak is so small that it is never seen, but the withdrawal of the sap results in either minute spotting of white, brown, or red on leaves, fruit, or twigs; or curling of the leaves; or deforming of the fruit; or a general wilting, browning, and dying of the whole plant (Fig. 2). Aphids, scale insects, the chinch bug, the harlequin cabbage bug, leafhoppers and plant bugs are well-known examples of piercing-sucking insects (see Fig. 63, p. 116).

Aphids (plant lice) (Fig. 63, *A* and *B*) are probably the most universal group of plant-feeding insects. There is scarcely a kind of plant, cultivated or wild, but what supports from one to several species of aphids, and a large percentage of the individual plants will be found infested each summer. The innumerable beaks of these little pests continuously pumping sap from the plants constitute a very severe drain on their vitality. It curtails growth, and interferes with the size and flavor of the fruit developed, if, indeed, the plant is not killed outright. The pea aphid, for example, (Figs. 298 and 299) caused in one year, in Wisconsin, a 50 per cent loss of the pea crop over 50,000 acres. The average value of the crop is $40 to $50 an acre. On the average, the loss is thought to be about 10 per cent yearly. Even when the quantity of the yield is not appreciably reduced, the quality and flavor of the peas are depreciated, making it necessary for the commercial canners to add more sugar in an attempt to make up the deficiency. In one experiment a specially devised machine collected 11 pounds of these aphids from 2½ acres. It requires about 416,000 aphids to weight 1 pound. Accordingly, there must have been in this field nearly two million aphids to the acre of peas. The pea aphid is only one of many dozens of destructive aphids. Any one of the following kinds certainly occasions as great or greater annual losses: the corn root aphid, the rosy apple aphid, the woolly apple aphid, the green bug, or the melon aphid.

Another sap-sucking insect, the San José scale (Fig. 63, *E* and *F*), has killed tens of thousands of acres of fruit trees since its introduction to the eastern states in 1886 and 1887. Even in recent years, when the lime-sulphur spray has held it in check very generally, it has proved to be seriously destructive in some sections. For example, more than one thousand acres of commercial apple orchard were killed by this pest in Illinois alone during the years 1921 and 1922.

The chinch bug (Fig. 63, *H*), since its first recorded outbreak in the United States in 1783, has destroyed more than $1,000,000,000 worth of grain crops. In 1914, this insect caused the loss of more than $6,000,000 worth of corn, wheat, and oats in 13 Illinois counties. There is scarcely a year when the farmers of the Mississippi Valley do not have to reckon with this insect in the production of their crops.

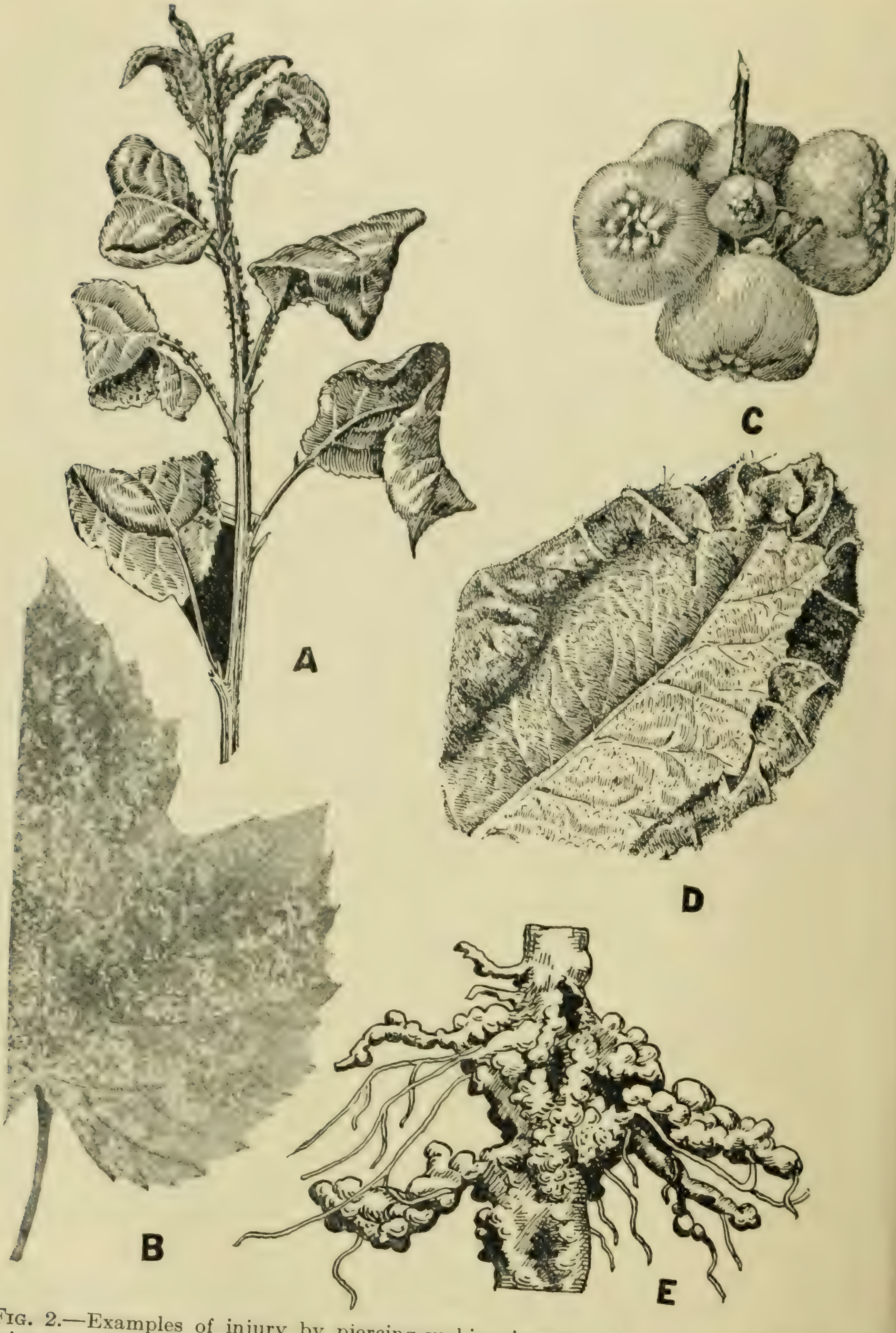

FIG. 2.—Examples of injury by piercing-sucking insects. *A*, curling of leaves and stunting of terminal growth by the green apple aphid (*from Quaintance and Baker, U. S. D. A.*); *B*, minute, white spotting, caused by the feeding of grape leafhoppers (*from Slingerland*); *C*, aphid apples, the result of the feeding of rosy apple aphids (*from Fulton*); *D*, hopperburn or tipburn caused by the feeding of apple leafhoppers on potato (*from Dudley, U. S. D. A.*); *E*, galls on roots of apple caused by the feeding of woolly apple aphids. (*Original.*)

These two groups of insects, the chewing and the piercing-sucking, are the ones for which most spraying is done. It would be difficult to say which group is the more injurious on the whole; but it may be said that the piercing-sucking kinds are generally more difficult to control.

Injury by Internal Feeders

So long as an insect feeds externally upon crops, it can usually be destroyed by the application of the proper insecticide. But many of our worst pests feed *within* the plant tissues during a part or all of their

Fig. 3.—Seven-inch trunk of black oak tree tunneled by larva of one of the long-horned beetles. The broad tunnel in the inner bark, below, represents the work of the first year of the insect's life. (*From Illinois State Natural History Survey.*)

destructive stages. They gain entrance to the plant either by having the egg thrust into the tissues by the sharp ovipositor of the parent insect, or by eating their way in after they hatch from the eggs. In either case, the hole by which they enter is almost always very minute, often invisible. A large hole in a fruit, seed, nut, twig, or trunk generally indicates where the insect has come out and not the point where it entered.

The chief groups of internal feeders are indicated by their common group names: (*a*) "borers," (*b*) "worms," in fruits, nuts or seeds, (*c*) "leaf miners," and (*d*) "gall insects." Each group except the third contains some of the foremost insect pests of the world. In nearly all of them, the insect is *internal* in only a part of its life stages, sooner or later emerging for a period of free living, usually as adults. This often affords an opportunity to control internal insects by dusting or spraying before their progeny gains entrance to the plant again.

Borers (Fig. 3) may attack any plant or part of a plant large enough to contain their bodies. Fruit and shade trees and many herbaceous plants suffer severely in this way. Various bud moths eat out the succulent tissues of swelling buds of trees. The bark beetles, the flat-headed borers and the peach-tree borer work chiefly in the vital cambium layer of twigs or trunk. The round-headed borers tunnel through the heartwood, as well as the cambium, greatly weakening the tree and damaging it for lumber. The corn earworm feeds on growing corn kernels underneath the husks at the tip of the ear. The European corn borer and stalk borers of several kinds tunnel throughout the stems of corn plants from tassel to roots. To cite just one instance in this group, it has been estimated[1] that in its worst years, more than 70 per cent of the ears of field corn the country over are attacked by the corn earworm, with the actual consumption of from 1 to 17 per cent of the grain in the infested ears.

Borers in fruits, including nuts and seeds, are generally called *worms* or *weevils*. Notorious examples are the codling moth (Fig. 61, *E*), bean weevils, the cotton-boll weevil, the plum curculio, the melon worm, the apple maggot and the chestnut weevil. Sometimes only one life stage is spent in the fruit, as with the codling moth and apple maggot; in other cases egg, larva, and pupa are all thus concealed from external attack; while in the bean weevil and granary weevil almost the entire life history is spent inside the seeds.

The cotton-boll weevil (Fig. 270) inserts its eggs into holes made by its long snout in the tissues of the developing bolls from which the cotton lint should later unfold. The grubs that hatch from these eggs devour the immature lint so that no cotton is secured from the infested bolls. Entering this country into southeastern Texas from Mexico in 1890, by 1900 it had increased and spread to such an extent that whole counties were destitute. Their one crop, cotton, having failed, their credit was gone; families became needy; farms were deserted; merchants went bankrupt; and banks failed. The loss increased rapidly in succeeding years until it reached the stupendous sum of $1,000,000,000 in a single year. The beetle has spread northward and eastward at an average rate of about 60 miles a year, until now all of the important

[1] See *U. S. Dept. Agr., Farmers' Bull.* 872, 1922.

cotton-growing states have been invaded (see Fig. 271). Recent discoveries of improved methods of control have greatly checked these losses, but still in 1923 the cotton-boll weevil harvested more than half of all the cotton planted in the United States. This one insect has collected a toll of nearly $3 a year from every acre of cotton land in the United States.

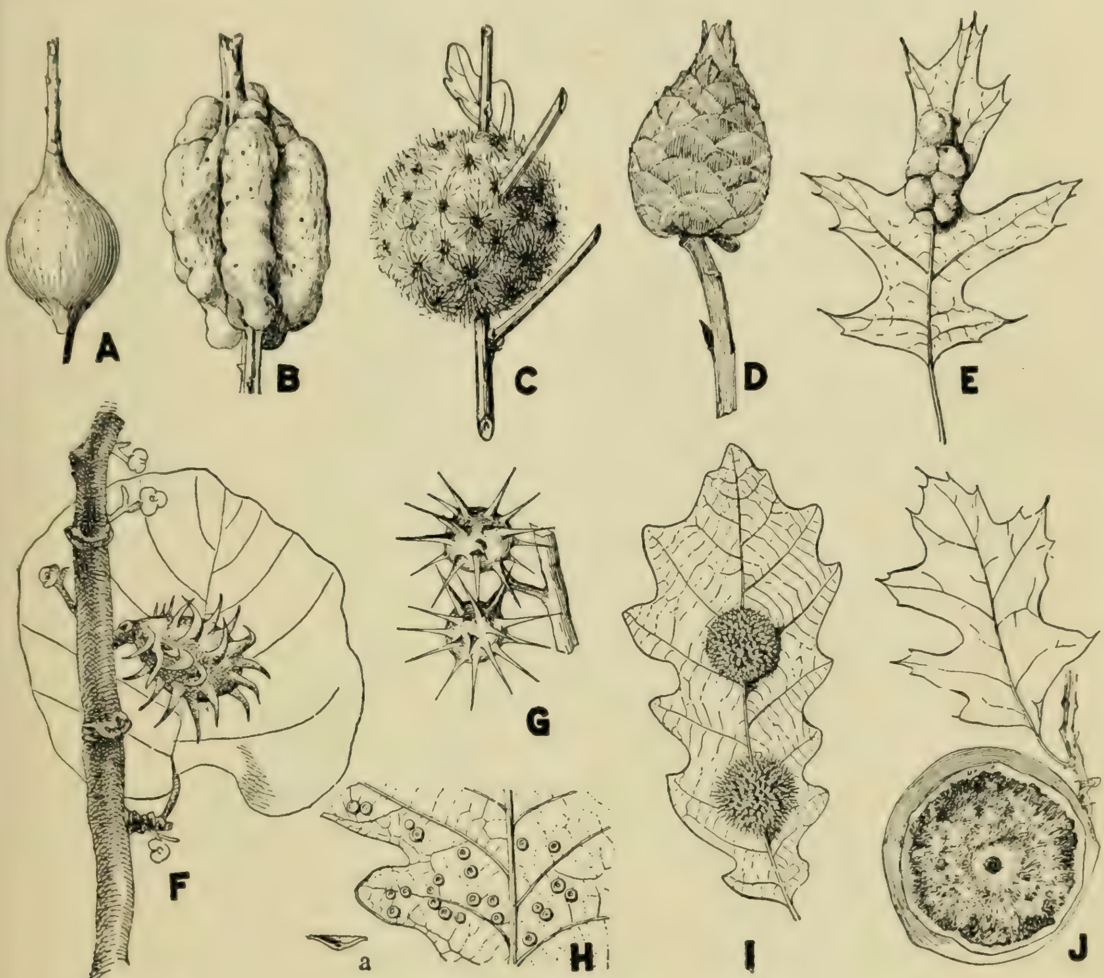

Fig. 4.—A group of insect galls. *A*, goldenrod ball gall, caused by a fly, *Eurosta solidaginis* Fitch; *B*, blackberry knot gall, caused by a gall wasp, *Diastrophus nebulosus* O. S.; *C*, wool sower gall on oak twig, caused by a gall wasp, *Andricus seminator* Harr.; *D*, pine cone gall, a common growth on willow, caused by a gall fly, *Rhabdophaga strobiloides* Walsh; *E*, dryophanta galls on oak leaf, caused by a gall wasp, *Dryophanta lanata* Gill; *F*, spiny witch-hazel gall, caused by an aphid, *Hamamelistes spinosus* Shim.; *G*, spiny rose gall, caused by a gall wasp, *Rhodites bicolor* Harr. *H*, oak spangles caused by a gall fly, *Cecidomyia poculum* O. S., one gall shown in section at *a*; *I*, spiny oak gall, caused by a gall wasp, *Philonix prinoides* Beutm.; *J*, *large oak apple*, caused by a gall wasp, *Amphibolips confluens* Harr. (*From Felt, "Key to American Insect Galls," N. Y. State Mus. Bull.* 200.)

A number of internal feeders are small enough to find comfortable quarters and an abundance of food between the upper and lower epidermis of a leaf and are known as *leaf miners*. Surely these are the things Lowell had in mind when he said "There's never a leaf nor a blade too mean to be some happy creature's palace." Among the

injurious forms are the apple leaf miners, beet leaf miner, spinach leaf miner and many others.

The *gall insects* "sting" the plant and make it grow a home for them, within which they find not only shelter but also suitable and abundant food. This is probably the most marvelous instance in biology of the profound influence exerted over one organism by another. We do not know as yet exactly what it is that makes the plants, when attacked by the insect, grow these curious, often elaborate structures (Fig. 4) that are absolutely foreign to them in the absence of the gall insect. A strange feature of the work of gall insects is that the same species of insect on different species of plants causes galls that are similar; while several species of insects attacking the same plant cause galls that are greatly different in appearance. Although the gall is entirely plant tissue, the insect in some unknown manner controls and directs the form and shape it shall take as it grows. There is a marvelous variety of such homes for insects built by the "unwilling" but helpless plants.[1] Many of these galls seem to be practically harmless to the plant that grows them. The wheat jointworm, however, one of our worst pests of wheat, is a gall insect, and the grape phylloxera has destroyed thousands of acres of the most valuable vineyards in Europe and America.

Injury by Subterranean Insects

Almost as secure from man's attack as the internal feeders are those insects that attack plants below the surface of the ground. These include chewers, sapsuckers and root borers, the attacks of which differ only from the above-ground forms just described in their position with reference to the soil surface. The subterranean insects may spend their entire life cycle below ground, as the woolly apple aphid. This insect, both as nymphs and adults, sucks the sap from the roots of apple causing the development of ugly tumors (Fig. 2, *E*) and the subsequent decay of the roots at the point of attack. More often there is at least one life stage of the insect that has not taken up the subterranean habit, as in the case of the white grubs, wireworms, Japanese beetle, root maggots, and grape and corn rootworms, in all of which the larvæ are root feeders while the adults have largely retained the more primitive life above ground. Interesting gradations and adaptations to the subterranean life are seen in the way in which the eggs of these insects are laid and in the place of pupation. In general it may be said that the more of its life stages the insect spends underground, the more difficult it is to control.

[1] See Felt, E. P.: "Key to American Insect Galls," *New York State Museum Bull.* 200, 1917.

Injury by Laying Eggs

Probably 95 per cent or more of the direct injury to plants is caused by insects feeding in the various ways just described. There is another instinct that pervades

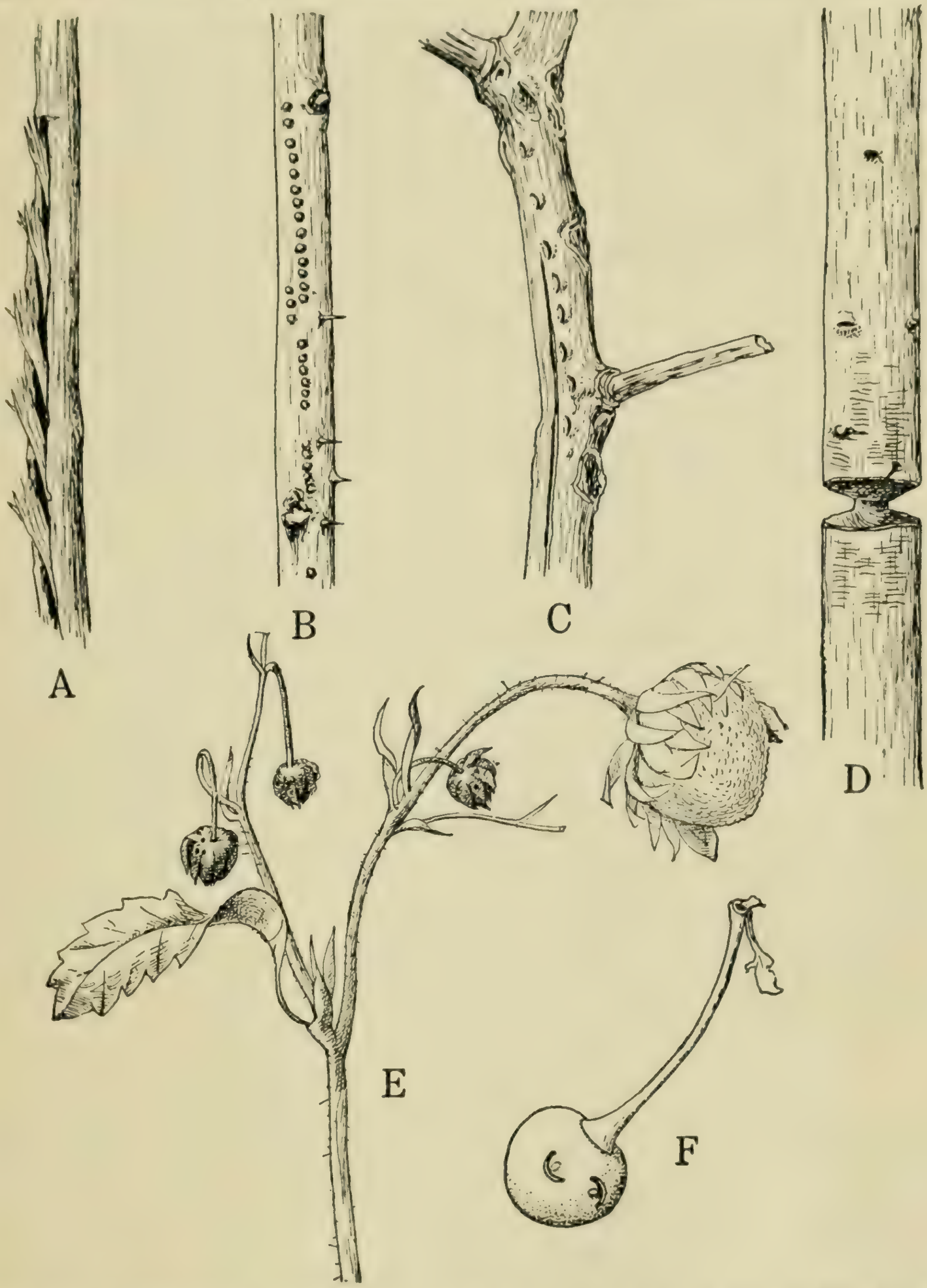

Fig. 5.—Examples of injury to plants caused by the egg-laying of insects. *A*, twig split by egg-laying of the periodical cicada; *B*, holes in stem of raspberry made by egg-laying of a tree cricket; *C*, slits in bark of apple twig beneath which a treehopper has thrust her eggs; *D*, twig of pecan cut nearly in two by egg-laying female of the twig girdler; *E*, fruit buds of a strawberry, partially severed by strawberry weevil after laying an egg in the buds; *F*, cherry showing two egg punctures of the plum curculio. (*A, B, C, D, and F, original; E, from N. J. Agr. Exp. Sta., after U. S. D. A.*)

animal life, including insects; namely, the instinct to provide for the welfare of the offspring. While, in general, the maternal instinct is poorly developed among insects, there are some very striking cases of great effort and care in the preparation of a nest

or the deposition of the eggs. Sometimes this provision for the young leads to serious injury to man's possessions. The periodical cicada[1] deposits her eggs in the one-year-old growth of fruit and forest trees, splitting the wood so severely that the entire twig beyond this point often dies (Fig. 5, *A*). The treehoppers and tree crickets split and ruin the bark or twigs of raspberry, currant and apple, in pushing their eggs into the plant tissues (Fig. 5, *B* and *C*). It is interesting to note that these are purely nesting sites. As soon as the young hatch, they desert the twigs and injure the plant no further. In other cases, the young, at least, subsequently feed upon the plant attacked by the egg-laying female; but we wish to call attention in this paragraph, to the injury by the egg-laying act, quite independent of any subsequent feeding of the young. Thus the plum curculio ruins the fruits of apple, plum, peach, and cherry by her characteristic egg-laying punctures (Fig. 5, *F*). The strawberry weevil, after laying an egg in the unopened bud, cuts the blossom stem partly off so that the flower never opens (Fig. 5, *E*). One of the most extreme cases of devotion to the welfare of the young is that of the twig girdler. In order that the larvæ of this insect may have wood in a suitable condition of moisture and decay, the female laboriously cuts off with her mouth parts twig after twig of oak, hickory, pecan, elm, persimmon, or other tree in which to lay her eggs (Fig. 5, *D*). The severing of a single twig requires several days of work by the female.

The Use of Plants for Making Nests

Besides laying eggs in plants, insects sometimes remove parts of the plant for the construction of nests or for provisioning nests elsewhere, though they do not feed on these materials. This injury is more interesting than it is serious. Leaf-cutter bees thus nip out rather neat circular pieces of rose and other foliage which are carried away and fashioned and cemented together to form thimble-shaped cells one above the other in a tunnel previously made in the stem of a plant. Each cell when completed contains a mass of nectar and pollen and an egg completely surrounded by bits of leaf; in this nest the young bee develops. The leaf-cutting ants strip the leaves from trees or herbaceous plants and carry them into their nests where they are cut into fine pieces, sometimes mixed with bits of their own or other insects' excreta, and form the medium upon which fungi are grown, as the only food of both larvæ and adults. Other kinds of ants hollow out the stems or thorns of plants in which they dwell; but this phase of injury is not serious to man.

Insects That Care for Other Insects

There is another way in which insects become serious pests. Ants, and some other kinds of insects which are not in themselves serious pests, become injurious because they bring to our cultivated crops (corn, citrus fruits, etc.) such noxious forms as aphids and mealy bugs, which are cared for and protected by them because they like to eat the honeydew secreted by these pests. In some cases, the most intricate and intimate interrelations have grown up between the ants, on the one hand, and the aphids, on the other. Such cases of mutual dependency of two organisms upon each other are known as *mutualism*. One of the best examples is furnished by the corn field ant and the corn root aphid. This destructive aphid (Fig. 203) has become totally dependent upon the ants, which care for the aphid eggs over winter, and in the

[1] Also called "seventeen-year locust."

spring and throughout the summer carry the young aphids in their mouths through underground tunnels and actually place them on the roots of corn and weeds on which the aphids can feed. The ants are paid for this solicitous care with the sweet honeydew, which the aphids continually secrete and which serves as food for the ants. The corn field ant is thus a menace to the corn crop although the ants themselves probably never injure the corn plant in any way.

Insects That Carry Plant Diseases

A serious phase of insect injury, and one which may prove to rival in importance that caused by the direct feeding of insects, is the newly discovered connection of insects with the transmission of plant diseases. In feeding upon a plant, the amount of damage that the insect does is more or less limited by the amount of tissue that it can devour; but if the insect's mouth parts are contaminated with disease organisms, the organisms may be established on the plant and not cease their attack until the entire plant is killed. In this connection Gardner[1] has pointed out that much more effective control is needed for these disease-carrying insects than for insects which harm the plant only by their feeding. Nothing short of absolute control is satisfactory for the disease carriers, because a single insect may deal the plant a death blow by inoculating it with a disease organism, whereas the *feeding* of one insect would be ordinarily insignificant.

The epidermis of plants, like the skin of animals, has a highly protective function. When it is broken an opportunity is afforded for the entrance of various destructive organisms. The attacks of the corn earworm (Fig. 234), already mentioned, are almost always followed by destructive molds and rots (some of them dangerous to animals which may eat them) that would not gain entrance to the ear were it not for the pathway prepared by the worm. The egg punctures and feeding punctures of the plum curculio (Fig. 5, *F*) are thus commonly starting points for the brown rot of the peach. The organism causing early blight of potatoes is similarly favored by the numerous holes made in the leaves by flea beetles (Fig. 61, *I*); chestnut blight, by the various bark beetles and borers attacking this tree; and the bacterial boll rot of cotton by boll weevils and bollworms.

In addition to thus passively favoring plant diseases, certain kinds of insects have been found actually to carry the pathogens on or in their bodies from plant to plant; and, as they feed, they introduce these disease germs into the plant tissues. The active, flying insects serve admirably to disseminate widely and rapidly these inactive disease organisms which by their own efforts could seldom get from one plant to another. Fire blight of apple and pear is carried by aphids, by bees,

[1] In *Phytopathology*, Vol. 12, pp. 225–240, 1922.

and by other insects that feed on these trees, and as they feed introduce the destructive fire blight bacillus. The fungi causing apple canker and raspberry-cane blight are swallowed by insects, carried about in their digestive tracts, and subsequently expelled in a viable condition.

In all of the above cases, the disease may and probably does survive and spread to some extent without the help of the insects. In the following cases, however, it seems that the regular means of spread of the disease from one plant to another is by the intervention of some particular insect. In at least a part of these cases it appears that the insect is necessary to the continued development and life of the pathogen, an essential part of its life cycle taking place in the insect's body. The best known case in this category is the cucurbit wilt disease carried by the striped cucumber beetle (Fig. 301) and the spotted cucumber beetle (Fig. 200). The causal organism of the disease spends the winter in the digestive tract of the hibernating beetles. Those which are so infected, when they begin feeding upon young cucumber plants in the spring, deposit in their feces some of the wilt bacteria. These are later washed over the surface of the leaf by dew or rain and, wherever there is a fresh wound opening into the vascular system of the leaf, the disease may become established. Probably the wounds, which are necessary to infection, are chiefly made by the insects in feeding. After the disease is started in this way, any cucumber beetle feeding on the plant may contaminate its mouth parts and then infect the next plant on which it feeds. No other means of spread for this disease are known. A similar relation exists between the olive fly and the olive-knot organism.[1]

In the case of the mosaic diseases or infectious chloroses of plants, no causal organism has been found. Presumably, they are too small to be seen with the highest powers of our microscopes. Nevertheless, it has been clearly shown that the only means of transmission of some of these diseases is the insect carrier. Thus curly-leaf disease of sugar beets is contracted by the plant only when it is punctured by the beet leafhopper which also carries the disease over winter. The tip-burn of potatoes (one of the most serious potato troubles) (Fig. 2, *D*) appears only on leaves that have been pierced by the apple leafhopper (Fig. 311). In a similar way insects such as aphids and the tarnished plant bug account for the appearance on previously uninfested plants of mosaic diseases of sugar cane, spinach, potato, tobacco, cucumber, cabbage, clovers, raspberry, and many less important plants.[1]

The importance of the subject opened up by the recent discoveries just cited, time alone can tell. However, the facts that these mosaic diseases attack so many of our most important crops; that they are very destructive; that they appear to be increasing in importance year after

[1] The student should consult the summary and bibliography of this subject contained in *Phytopathology*, Vol. 12, pp. 225–240, 1922.

year; and that insect carriers have been discovered for these troubles in more than 60 different kinds of plants; point to the probability that this is one of the most serious methods of injury by insects, constituting one of the most promising and at the same time most difficult fields for future investigation.

B. INSECT INJURY TO MAN AND OTHER LIVING ANIMALS

The second great group of things that fall prey to insects, is all manner of animal life, from protozoa to man. We find no records of insects that feed upon the marine animals known as Echinoderms. With this exception all of the principal branches of the animal kingdom are attacked. Insects in their relation to us make no distinction between man and other animals and we shall make none in this discussion.

Annoying Insects

There are, first of all, a number of minor ways in which insects conflict with man's comfort and pleasure. All of us have experienced great annoyance from flying,

Fig. 6.—A cow being chased by an ox warble fly, intent on laying its eggs. Note the terrified look of the eyes. (*From Hadwen, Canada Dept. Agric. Health of Animals Branch, Sci. Ser. Bull.* 27.)

buzzing, or crawling creatures at times, particularly when we desired to rest or apply ourselves to some exacting task. The unpleasant taste left by certain stink bugs on an otherwise edible raspberry, the disgusting odor of cockroaches about the table service of many restaurants, and the sharp pain caused by getting certain minute insects[1] into the eye when driving at night are familiar examples of annoyance by insects. The accidental invasion by living insects of the ears, nostrils, or stomach is usually serious but fortunately a rare experience. Animals suffer from the attempts of certain flies (the botflies) to lay eggs on their bodies. Although it is claimed that only a nervous injury and not a physical one accompanies this attack, it is sufficient to cause the wildest stampeding of cattle, horses, and deer (Fig. 6). While these annoyances

[1] For example, staphylinid beetles and certain small Hemiptera.

constitute the least important of all the phases of insect injury to animals, still they are sufficient to account for a great deal of monetary loss, discomfort, and inefficiency.

Venomous Insects

Insects are not popular. The innate abhorrence of "crawling things" possessed by some persons is unfortunate, however, because it prevents them from learning anything about insects and interferes unnecessarily with their enjoyment of out-of-door life. An extreme fear of bugs, caterpillars, spiders, and bees is not warranted by the facts. In temperate climates, there are very few kinds of insects that can harm the body seriously. Nevertheless, there are a number of kinds that can bite and sting painfully and these wounds may become infected, with serious results. It is so often true as to be almost a rule that the worst-looking forms are generally harmless; while some of the most painful experiences result from contact with very innocent-looking specimens.

Bodily pain and illness may be caused by the venoms of insects applied to the body in the following ways: (*a*) by the mouth parts—either inserted to secure food or applied in a defensive way when certain insects are handled; (*b*) by a "stinger," a defensive and offensive organ located near the tip of the abdomen; (*c*) by hollow poison hairs on the body of certain caterpillars, that inject venom after the manner of the common nettle plants; (*d*) by the application of caustic or corrosive fluids to the skin; (*e*) by swallowing insects that contain a poisonous principle.

A certain amount of pain may result from mere mechanical injury by insects as when a boy finds a "pinching bug" for the first time. But the really painful bites are accompanied by the introduction of a venom and, therefore, are a chemical injury. The nature of the venom appears to vary but has the common characteristic that it is in some way toxic to animal tissues and so causes pain. It is interesting to note, for example, that Schaudinn[1] seems to have proved that the irritation from a mosquito bite is due to an enzyme from a kind of yeast plant that lives as a commensal in the lobes of its stomach and that is expelled into our flesh as the insect bites.

Besides the spiders, ticks and centipedes, the following kinds of true insects are notorious for the injury inflicted by their bites: the Diptera or two-winged flies; including mosquitoes, black flies, horseflies, the stable fly, tsetse flies, the sheep tick, etc.; the Hemiptera or true bugs, including the bedbug, assassin bugs, back swimmers, water scorpions, etc.; the Anoplura or blood-sucking lice; the Siphonaptera or fleas.

Many insects regularly feed on animal blood, including that of man, as their only food; and while so feeding, usually introduce a poison that causes a painful irritation. Many sections of the mountains and woods are rendered temporarily uninhabitable by swarms of black flies in early summer. Forbes[2] quotes from Agassiz's "Lake Superior" as follows:

"Nothing could tempt us into the woods so terrible were the black flies. One, whom scientific ardor tempted a little way up the river in a canoe, after water plants, came back a frightful spectacle, with blood-red rings around his eyes, his face bloody, and covered with punctures. The next morning his head and neck were swollen as if from an attack of erysipelas".

The stable fly (Fig. 522), that dreaded but constant companion of horses, mules, cattle, and hogs, all summer long, inflicts such painful bites and withdraws so much

[1] See Riley and Johannsen: "Handbook of Medical Entomology," p. 34 *et. seq.*, 1915.

[2] Forbes, S. A.: "The Insect, the Farmer, the Teacher, the Citizen and the State," Ill. State Lab. Nat. Hist., 1915.

blood that animals are sometimes killed outright. Unable to don protective clothing, to retreat into screened houses, or even to "swat" efficiently, domestic animals must suffer beyond our comprehension from these many, bloodthirsty pests. This suffering is translated into losses to the livestock farmer in decreased milk yield, loss of flesh, unsatisfactory growth, inefficiency and unmanageableness of work animals and in greater susceptibility of the weakened animals to diseases.

The other methods of applying a venom are much less important than that by biting. The stinging insects are, so far as man and the larger animals are concerned, largely a peaceable and defensive lot, inflicting their punishment almost exclusively on creatures that have injured them or threatened their homes. The sting is, indeed, used without provocation against other insects and the like which are taken as food;

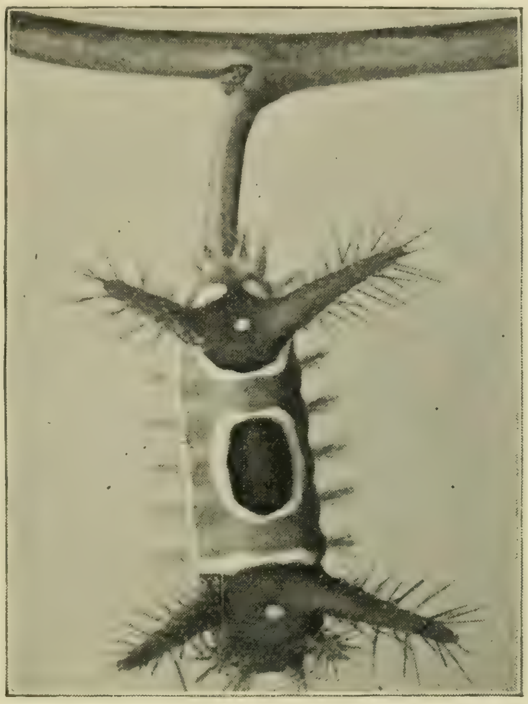

FIG. 7.—A caterpillar with poisonous hairs, the saddle-back, *Sabine stimulea* Clemens, about natural size. (*From U. S. D. A. Farmers' Bull.* 1495.)

and Herms[1] records that a California farmer claims to have lost 400 small pigs during one year, due to the stings of myriads of ants.

Some of the ants possess a venom but have lost the stinger with which to inject it. According to Wheeler, these spray the poison from the tip of the abdomen into a wound made by the mouth parts. Certain beetles have a similar method of defense. Some ground beetles[2] have been known to eject an acrid fluid which is discharged with a distinct popping sound and a small cloud of vapor that looks like the smoke from a miniature cannon.

Among the most interesting protective structures that insects possess are the nettling hairs of many caterpillars. These structures are similar to the poison hairs of the nettle plant. Not all the hairs of the body are of this type but only certain ones are hollow and connect at their base beneath the cuticula with a poison gland cell.

[1] HERMS, W. B.: "Medical and Veterinary Entomology," 2nd ed., The Macmillan Company, 1926.

[2] Bombardier beetles, *Brachinus* spp., Order Coleoptera, Family Carabidæ.

When these hairs penetrate the human skin the poison is released at a broken point and may create a serious skin eruption accompanied by intense itching and intestinal disturbance.

The following are the best known of the nettling caterpillars: the brown-tail moth, (Fig. 470) the io moth, the saddle-back caterpillar (Fig. 7), the flannel moth, the hag moth, and the buck moth. There is nothing distinctive about the appearance of these stinging caterpillars as a group. One has simply to learn to recognize each of them. As pointed out already, there are many, more formidable-looking kinds that are totally harmless. For example, the hickory horned devil (Fig. 8) with his many, thorny spines, some of them ¾ inch long; the common tomato worm (Fig. 318) and other

Fig. 8.—An entirely harmless, though evil-looking caterpillar, the hickory horned devil (*Citheronia regalis* Fab.), about one-fifth smaller than natural size. (*From Houser, after Packard.*)

sphingid larvæ with a pointed horn near the tail end of the body; the celery caterpillar (Fig. 140, *b*) with a pair of soft yellow horns near the head that are erected and thrust out when it is disturbed and give off a peculiar odor; these and many other dangerous-looking forms are absolutely incapable of harm to the person.

There are also certain insects that carry a venomous substance diffusely throughout the body, especially in the blood, rather than confined to particular glands. In some cases, notably the blister beetles[1] (Fig. 258), this poison possesses caustic or blistering properties when the insects are accidentally crushed on the body. They are also poisonous if taken internally, as when cattle eat them while grazing. Chickens are often killed by feeding upon the rose chafer (Fig. 423) in localities where it is abundant, and Lamson has shown that death results from an unknown poison contained in the bodies of these beetles.

[1] Order Coleoptera, Family Meloidæ.

External and Internal Parasites

The most loathsome attack we suffer at the hands of insects is their very common habit of taking up their residence on or within our bodies or those of domesticated animals. Such insects are called *zoophagous parasites*. Many insects lay their eggs on animals and live continuously on their hosts, generation after generation, never leaving them except as the hosts die or as they instinctively transfer from older to younger animals of the same species. Others spend certain life stages or certain parts of the day on the host and are free living the rest of the time. Some of these lay their eggs on the host but desert it in their later stages (for example, botflies); others lay eggs and develop away from the host and then become parasites only as adults (for example, fleas).

Three entire orders of true insects, namely the chewing lice (Mallophaga), the blood-sucking lice (Anoplura) and the fleas (Siphonaptera), a total of more than 2,500 described species, are entirely parasitic; besides hundreds of species from among the flies (Diptera) and true bugs (Hemiptera) and hundreds more of the ticks and mites of the class Arachnida.

The greater number of these species live externally on the surface of the skin. Their constant crawling about on the skin causes nervousness, restlessness, loss of sleep, failure to feed and thus a general "run-down" condition and increased susceptibility to diseases. Their excreta, and especially the eggs of those that are attached to feathers or hairs, mat the coat and create a foul condition that interferes with the excretory function of the skin. All of these external parasites, except the order Mallophaga, feed by inserting their mouth parts and pumping out the blood. When they are abundant, this irritation, intensified by the animal's rubbing or scratching, may lead to great sores as in the case of the scab mite of sheep (Fig. 542) or the body louse ("cootie") of man. In other cases serious constitutional disturbances result. The mites known as chiggers or harvest mites often give rise to chilliness, nausea, and vomiting. The insertion of the mouth parts of the Rocky Mountain spotted-fever tick at the base of the head of man or sheep is said to cause an ascending motor paralysis involving complete loss of the use of the limbs, and death, unless the tick is removed.

External parasites that suck the blood of the higher animals include such common pests as the hog louse, the sheep "tick," fleas, bedbugs, and the cattle tick. There is one kind of lice that does not suck blood. These are the so-called bird lice or chewing lice,[1] including all common poultry lice (Fig. 546) and certain species of lice found on horses, cattle, and other mammals. Their mouth parts are formed to cut off and ingest solid particles rather than to draw blood. They feed upon the dry skin, parts of feathers or hairs, clots of blood, and the like, and their

[1] Order Mallophaga.

injury is probably chiefly due to nervous irritation from nibbling at the skin and running about over it.

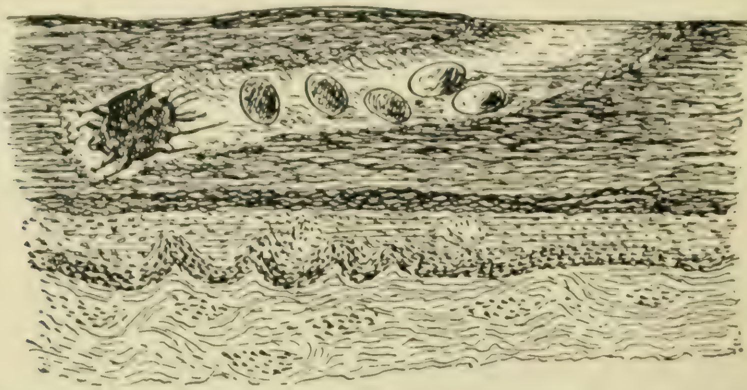

FIG. 9.—The itch mite tunneling into the skin of man to lay its eggs, several of which are shown. Diagrammatic and greatly enlarged. (*From Riley and Johannsen, "Handbook of Medical Entomology," courtesy Comstock Publishing Co.*)

FIG. 10.—A piece of grubby hide, after tanning, showing holes made by ox warble larvæ in the most valuable part of the hide, which render the leather practically useless. (*From Hadwen, Canada Dept. Agric., Health of Animals Branch, Sci. Ser. Bull. 27.*)

Internal insect parasites of the higher animals are of few kinds. But they are so troublesome to our livestock that they constitute a group probably more destructive than the external parasites. These internal

parasites are either mites (Acarina) or true flies (Diptera). With a few possible exceptions all internal insect parasites are *transitory*, that is they pass only a part of their life cycle inside the body. For example, in flies it is always the maggot stage that lives within the animal body; the adult, at least, living away from the host. In the mites, the young may be internal, but they live as external parasites on the surface of the skin for at least a part of the adult life.

Just as there are borers in plants, so there are insects that live as borers in the animal body. The itch mite, scaly-leg mite and their

FIG. 11.—Larvæ of a fly (*Phormia terræ-novæ* Desv.) found under the skin of a reindeer. When heavily infested, the animal usually dies. (*From Hadwen, U. S. D. A., Dept. Bull.* 1089.)

kind dig tunnels into the flesh, in which their eggs are laid (Fig. 9). This explains the intolerable itching that is the most prominent symptom of their attack. Before the cause of the disease was known, the "seven-year itch," as it was often called, was a most loathsome and persistent affliction.

We have spoken of the injury insects cause when they try to lay their eggs on the bodies of animals. The larvæ from such eggs are very serious parasites. For example, ox warbles cause serious damage to the hides of cattle which are rendered more or less useless for making leather (Fig. 10). The loss in value of the hides (augmented by the pain suffered by the animals, the depreciation in value of the carcass

for beef, the loss of milk flow, and decreased growth) amounts to about $50,000,000 a year in the United States. In Africa the tumbu fly attacks man in a manner similar to that of the ox warble in cattle. Another species of botfly causes lumps in the necks of rabbits.

The screw worm and other flies live in the flesh of cattle, horses, hogs, man and other animals during the maggot stage (Fig. 11). These flies are attracted by any wound such as a barbed wire cut, a dog's bite, dehorning or branding wounds, or even the spot where a tick has bitten an animal, or by foul secretions, nasal catarrh, bad breath and the like. In such situations the eggs are laid, and the larvæ tunnel about and feed, greatly aggravating the inflammation and suppuration of the wound and preventing its healing. It is necessary in the southwest to treat all wounds of animals on the range with a repellent, antiseptic dressing to prevent contamination by this pest. Fortunately such attacks upon human beings are rare.

In addition to the mechanical injury from these internal larvæ, Hadwen[1] appears to have shown that the larvæ of ox warbles secrete a toxin into the lymph of the host that may be very injurious.

A few kinds of insects, habitually, and some others, accidentally, live in the alimentary canal of animals. These should not be confused with the intestinal worms[2] which are not insects. The best known of intestinal insects are the several species of horse bots (Fig. 527). A horse that is heavily infested with bots generally presents a badly run-down condition. There are no insects that habitually live in the alimentary canal of man, but the eggs or small larvæ of blue-bottle flies, flesh flies, the house fly, rat-tailed maggots, and others may be swallowed with impure drinking water, milk or infested food. Their presence in the stomach generally causes symptoms of nausea, vomiting, and fever.

Insects as Carriers of Animal Diseases

The most complicated way in which insects injure man and his animals, and the most sinister of all their attacks is as carriers of disease organisms. Any disease in order to persist must continually find new hosts to supplant those lost by death: for the death of a host is calamitous to the parasites that caused it and must often be followed by the death of all the parasites on or in its body. The transfer of disease organisms to new hosts may take place during close association or bodily contact of a well animal with a diseased one, as in leprosy or smallpox; by way of the air, as in tuberculosis; through contaminated food or drinking water, as in typhoid fever; by contact with infected soil, as in hookworm; or by being carried by insects or other small arthropods.

[1] Hadwen, S.: *Dept. Agr. Can., Health of Animals Branch, Sci. Ser. Bull.* 27, July, 1919.

[2] Phylum Nemathelminthes.

In 1893, Smith and Kilbourne published their proof that the serious disease of cattle known as Texas fever (see p. 788) is caused by a protozoan parasite that lives within, and destroys, the blood corpuscles and is spread exclusively by the bites of the cattle tick (Fig. 531). This was a startling discovery of most far-reaching consequences. Following this, other similar discoveries came rapidly; so that within 30 years after the first proof of the insect transmission of any animal disease, we have a list of such cases that leads one to look upon these small arthropods as particularly menacing (Fig. 12).

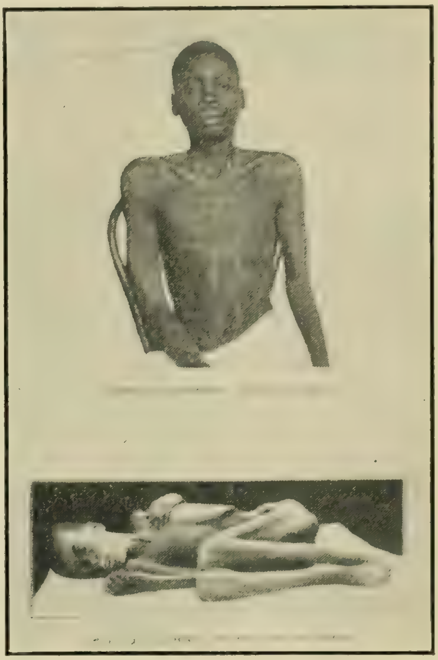

FIG. 12.—A victim of African sleeping sickness, a highly fatal disease carried to man exclusively by the bites of certain flies known as tsetse flies. (*From Osler's "Modern Medicine," Lea & Febiger.*)

A study of the accompanying table (Table I) will show the essential facts regarding some of the most important diseases of man and domestic animals, which are known to be carried by insects.

Many and varied are the ways in which these microscopic germs "ride" on or in the bodies of insects to a position where they can again increase in numbers and complete their life cycle at the expense of the health of some animal. They may "ride" on the hairy legs, wings or mouth parts of the insect or they may make the journey within the body of the insect—in the alimentary canal, body cavity, salivary glands, muscles, or Malpighian tubules.

These disease organisms may "alight" either on the food or drink of the next victim and attack its body after having been swallowed. Or they may alight from the insect directly on the body of the new host in some receptive place, such as the lips, the surface of the eye, a wound or sore. They cannot, as a rule, attack through the healthy unbroken skin. They may actually be injected hypodermically into the blood or lymph of an animal when the insect that carries them on its mouth parts pierces the skin to suck blood. They may drop or be rubbed off the insect's body when the journey is completed; pass out with the feces; be regurgitated in vomit spots; be pumped out with the saliva; or be swallowed by the new host, with the insect that carried them.

They may, during the journey to a new host, remain unchanged in the insect body. Or they may increase their numbers without a change of form. Or they may increase in numbers by a metamorphosis, passing through definite stages of their life cycle in the body of the insect that they cannot undergo in the body of any other animal or in any other

TABLE I.—SOME OF THE MORE-IMPORTANT INSECT-

Name of the disease	Animal affected	Carrier of the disease	Classification of the carrier	Pathogenic organism
Yellow fever.	Man	The yellow fever mosquito, *Aedes aegypti*	Class Hexapoda, Order Diptera, Family Culicidæ	*Leptospira icteroides* Noguchi, or unknown
Malaria.	Man	The malarial mosquitoes; about 50 species of the genus *Anopheles*	The same	*Plasmodium malariæ*, *P. vivax* and *P. quotidianum*
Filariasis or Elephantiasis.	Man	About a dozen species of mosquitoes	The same	*Filaria* (Microfilaria) *bancrofti*, and other species
Dengue.	Man	The mosquitoes, *Culex quinque-fasciatus* and *Aedes aegypti*	The same	Unknown; a filterable virus
African sleeping sickness.	Man	The Tsetse Flies, *Glossina palpalis* and *G. morsitans*	Class Hexapoda, Order Diptera, Family Muscidæ	*Trypanosoma gambiense* and *T. rhodesiense*
Nagana.	Domestic animals, wild game	The Tsetse Flies, *Glossina morsitans* and *G. longipalpis*	The same	*Trypanosoma brucei*
Typhus fever.	Man	The human louse, *Pediculus humanus*	Class Hexapoda, Order Anoplura, Family Pediculidæ	*Rickettsia prowazeki* da Rocha-Lima
Chagas disease.	Man	The assassin bug, *Triatoma megista*	Class Hexapoda, Order Hemiptera, Family Reduviidæ	*Schizotrypanum cruzi* Chagas
Bubonic plague.	Man, rat, ground-squirrel	Nine or more species of fleas	Class Hexapoda, Order Siphonaptera, Family Pulicidæ	*Bacillus pestis*
Typhoid fever.	Man	The house fly, *Musca domestica*	Class Hexapoda, Order Diptera, Family Muscidæ	*Bacillus typhosus*
Summer diarrhea.	Man	The house fly, *Musca domestica*	The same	Bacillus of Morgan
Texas fever or splenic fever.	Cattle	The cattle tick, *Margaropus annulatus*	Class Arachnida, Order Acarina, Family Ixodidæ	*Babesia bigeminum*
Rocky Mountain spotted fever.	Man	The spotted-fever tick, *Dermacentor venustus*	The same	*Dermacentroxinus rickettsi* Wolbach
Fowl spirochætosis.	Chicken, turkey, goose	The fowl tick, *Argas persicus*	Class Arachnida, Order Acarina, Family Argasidæ	*Spiroschaudinnia marchouxi*, *granulosa*, and *neuvexii*
Tsutsugamushi disease.	Man	A mite, *Leptotrombidium akamushi*	Class Arachnida, Order Acarina, Family Trombidiidæ	Unknown; a filterable virus

situation. In the latter case we say the insect is *an essential host* (besides being a carrier) of the disease-producing organism. The complication of these problems is increased in some cases by the fact that, besides the insect carrier, the disease organism may have at least two other hosts, one in which it causes a definite disease and another in which it appears to be harmless. The latter animals are known as *reservoirs* of the disease.

BORNE DISEASES OF MAN AND DOMESTIC ANIMALS

Classification of the pathogen	Distribution of the disease	Methods of transmission	Other ordinary ways of getting the disease
A Spirochete, or unknown	The tropics and subtropics of Africa and America	Directly inoculated into blood by mouth parts of mosquito	None. Exclusively insect borne
Phylum Protozoa, Subphylum Sporozoa, Class Telosporidia, Order Xenosporidia	In a broad belt around the globe between 4th i.l.N. and 16th i.l.S.	The same	None. Exclusively insect borne
Phylum Nemathelminthes Class Nematoda Family Filariidæ	Southern United States, Southern China, Africa, West Indies, Samoa, Tahiti	The same	None. Exclusively insect borne
	Around the globe in the tropics and subtropics	The same	None. Exclusively insect borne
Phylum Protozoa, Subphylum Mastigophora Order Trypanosomatida	Equatorial Africa	Directly inoculated into blood by mouth parts of the fly	Possibly other species of tsetse flies
The same	Equatorial Africa	The same	Possibly other species of tsetse flies
Bacteria Family Bacteriaceæ	Europe, Mexico	Deposited in feces by louse and scratched into skin	None. Exclusively insect borne
Phylum Protozoa, Subphylum Mastigophora Order Trypanosomatida	South America	The same or inoculated into blood by mouth parts of bug	Possibly by other blood-sucking Hemiptera
Bacteria Family Bacteriaceæ	Nearly cosmopolitan	Directly inoculated into blood by mouth parts of the flea	By breath of a plague victim or from fomites
Bacteria Family Bacteriaceæ	Cosmopolitan	Carried externally or deposited in fly's feces or vomit spots	From contaminated milk, water or food
Bacteria Family Bacteriaceæ	Cosmopolitan	The same	The same
Phylum Protozoa, Subphylum Sporozoa, Class Telosporidia, Order Xenosporidia	Southern United States, Central and South America, South Africa, Philippines, Europe	Directly inoculated into blood by mouth parts of the tick	None except by other species
Unknown	Western United States and Alaska; Bitter Root Valley of Montana	The same	None. Exclusively tick borne
A Spirochete	India, Australia, Brazil, North America, Persia, Egypt, etc.	The same	None. Exclusively tick borne
Probably Protozoa, Sporozoa	Japan and Formosa	Directly inoculated into blood by mouth parts of the mite	None. Exclusively mite borne

Thus, in the case of Rocky Mountain spotted fever, the spotted-fever tick (Fig. 556) is the carrier and man is the victim of the disease; but some other animal (probably a rodent) is believed to serve also to keep the causal organism alive in the absence of man; that is, to be a reservoir of the disease. Again the problem is complicated by the fact that the disease-causing organism may pass from an infected insect through its

eggs to the next generation of the insect to reappear in a virulent form again after a long period of latency.

It will be obvious that in the relation of insects to animal diseases just as in their connection with the spread of plant diseases we have a subject fraught with the greatest possibilities; one needing vastly more, careful investigation; and one calling for the close cooperation of expert entomologists, expert parasitologists and expert physicians, if man and his domesticated animals are speedily to be freed from many of their worst ailments.

C. INSECTS AS DESPOILERS OF STORED PRODUCTS AND OTHER MATERIALS

We have reviewed the methods of injury by insects to living plants and to living animals, including man. The third great phase of insect injury arises from the fact that they compete with us for the possession and use of practically all of our stored products—both stored foods and the many other articles with which we habitually surround ourselves. We find here, exactly as in the case with living plants and living animals, that the attacks of insects are motivated mostly by hunger. To a lesser degree, damage results from their efforts to make provision for their eggs or young or in seeking shelter or building nests for themselves.

Since hunger is the principal motive involved, and since insects eat organic matter of every kind, and practically only organic matter, it follows that the chief stored products to be protected are things of plant or animal origin, including grains, seeds, flour, meal, candies, nuts, fruits, vegetables, meats, fats, milk, cheese, honey, wax, tobacco, spices, drugs, feathers, furs, leather goods, woolens, paper, books, labels, photographs, boxes, furniture, wooden buildings, bridges, piling, mine props, telephone poles, railroad ties and trestles, and collections of insects, plants and animals. These are some of the things that must be guarded from insect depredations.

Many other things not of an organic origin are generally immune from attack; for example, jewelry, metals of all kinds, pottery, statuary, brick, stone, and cement work. Even these inorganic objects are not entirely inviolate by insects. A species of powder-post beetle has been given the name of lead-cable borer[1] because of its troublesome habit of eating holes through the lead sheathing of aerial telephone cables (Fig. 13). These holes admit moisture, cause short circuits, and often the insulation becomes water-soaked and ruined for an appreciable length, necessitating splicing and resheathing. In southern California this type of insect injury is reported as causing about one-fifth of all aerial cable troubles. As many as 125 holes to a span of 100 feet have been found. A single hole may put from 50 to 600 telephones out of use for

[1] *U. S. Dept. Agr. Dept. Bull.* 1107, 1922.

from 1 to 10 days. Termites similarly have bored through the lead pipe and the cotton insulations enclosing underground cables, thus ruining them within a year after they were laid down. Beetles of at least a dozen different families, besides the caterpillars of several moths and adult wasps of several kinds, have been recorded as boring through metal. Some years ago, one of the large railroads discovered that a mud-dauber wasp was causing great trouble and expense by building its mud nests in the exhaust port of the pressure-retaining valves of the Westinghouse

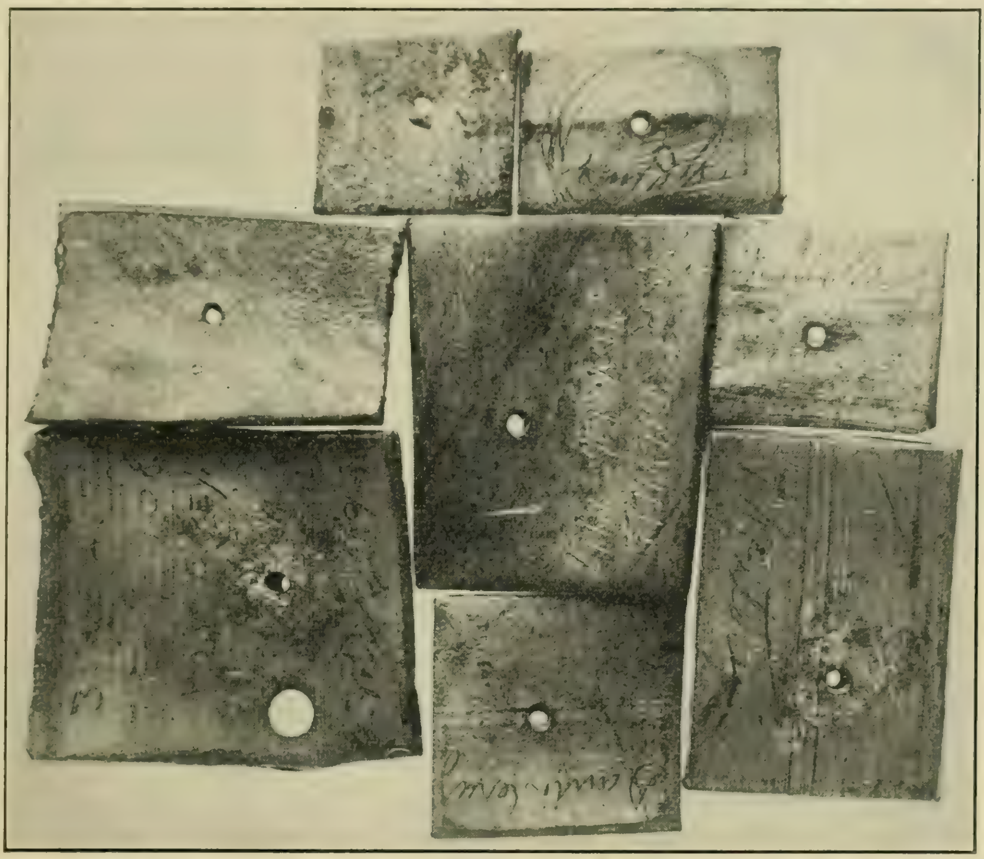

FIG. 13.—Holes bored in the lead sheathing of aerial cables by the California lead-cable borer (*Scobicia declivis* Lec.), from various localities in California. (*From U. S. D. A., Dept. Bull.* 1107.)

air brake. It became necessary to change the shape of the valve and the form of its opening to overcome the trouble.

FOOD-INFESTING INSECTS

While the above cases are spectacular, it must be borne in mind that the total injury by all of the insects that attack inorganic articles in all time past is probably exceeded in a single year by the injury of any one of a dozen or more pests of stored foods. The pests of stored products are the most expensive of all insects to feed, because to the cost of planting and cultivating their food must be added the cost of harvesting

and storing it and sometimes expenses for manufacturing, selling, and distributing the product.

In times of stress, attacks by insects upon man's food supply may mean death to thousands. In earlier times one of the critical duties of sailors upon long ocean voyages was to guard the ship's biscuits from the ever-present and ravenous cockroaches. During the World War, large quantities of wheat, badly needed by the European nations, were destroyed by weevils in Australia; and entomologists were hurriedly dispatched to check the destruction. Seeds are among the most concentrated foods known, and a large part of the injury to stored products is to seeds of our cereal and leguminous crops. Of the many animals that compete for this valuable food material in any community, such as birds, rats, mice, insects and man, insects probably get the largest share, next to man.

FIG. 14.—Ear of corn showing the silk webs formed by larvæ of the Indian meal moth, about ⅓ natural size. (*Reduced from U. S. D. A. Farmers' Bull.* 1260.)

Dr. Britton, State Entomologist of Connecticut, estimated in 1917 that it costs the American people $200,000,000 a year to feed the insect pests of stored foods. Every individual can recall some case where an article of food had to be discarded because insects "beat man to it." These small losses make in the aggregate a heavy total. And to the total of small losses must be added all-too-frequent cases where an entire crop in storage, the contents of a large elevator, or a shipment of food stuffs has been rendered unfit for human consumption.

The method of attack is varied. Some species hide their eggs in the developing seeds as they grow in the field and the injury becomes apparent only after the immature insects have been carried into the store-house. Such is the case with the bean and pea weevils (Figs. 516 and 517) and the Angoumois grain moth (Fig. 513). Other kinds enter by stealth into kitchens, granaries, or factories and deposit their eggs on cured meats, harvested seeds, or any of the products manufactured from the raw-food materials. Some of the grain insects make their homes inside of single whole grains during all of their growth; others attack only the broken or ground seeds, roaming about in flour, meal, and other foods and contaminating much more than they eat, with their excreta or the silk that they spin (Fig. 14). Many other kinds do not breed in the stored foods, either having nests outside and entering our foods only on foraging expeditions, like the ants; or leading a gypsy life, like the cockroaches, which are objectionable more on account of the filth and disease

germs that they probably carry, than because of the amount of food consumed.

Two orders of insects are of prime importance as pests of stored foods: (*a*) the Coleoptera, including such notorious pests as the granary weevil (Fig. 508), the confused flour beetle, the saw-toothed grain beetle, the pea weevil, the bean weevils, the larder beetle, and many others; and (*b*) the Lepidoptera, including the Angoumois grain moth, the Mediterranean flour moth (Fig. 514), the Indian meal moth, and others. In the former of these groups, both the grubs or larvæ and the adult beetles feed on the stored materials, while among the moths only the caterpillar is directly injurious. In addition to these two groups of most importance,

FIG. 15.—A public building, the foundation timbers of which have been badly damaged by termites, necessitating extensive repair work. (*From photo by Snyder, U. S. D. A.*)

such scattered pests as the book louse, the cheese skipper, the cheese and ham mites, and the red-legged ham beetle sporadically destroy large quantities of food.

No other economic group is more widely and equitably distributed than these insects of stored products. Many of the worst kinds are quite cosmopolitan. Some of them have been said to have spread over an entire continent in two or three years. They crawl and fly about seeking the concentrations of attractive foods that we bring together; they enter our storehouses on the crops we harvest; they are distributed in the seeds we purchase for planting; they go to market with the grains we sell; and they come back to us in the flour, breakfast cereals, cakes, and crackers from our grocers.

PESTS OF WOOD AND WOODEN ARTICLES, CLOTHING, AND DRUGS

A particularly insidious pest is the termite, or white ant (Fig. 497), whose fondness for a diet of woody tissues leads to most surprising invasions of dwellings (Fig. 15), libraries, trestles, mine timbers, and indeed any article of wooden origin, such as stores of paper stock, cardboard boxes, library books (Fig. 16), and the like. This species avoids the light, works always inside the structure invaded, and as a result may gain great headway in a building before it is detected. Many cases are on record of extensive damage to private and public buildings by this insect, and its numbers seem to be on the increase.

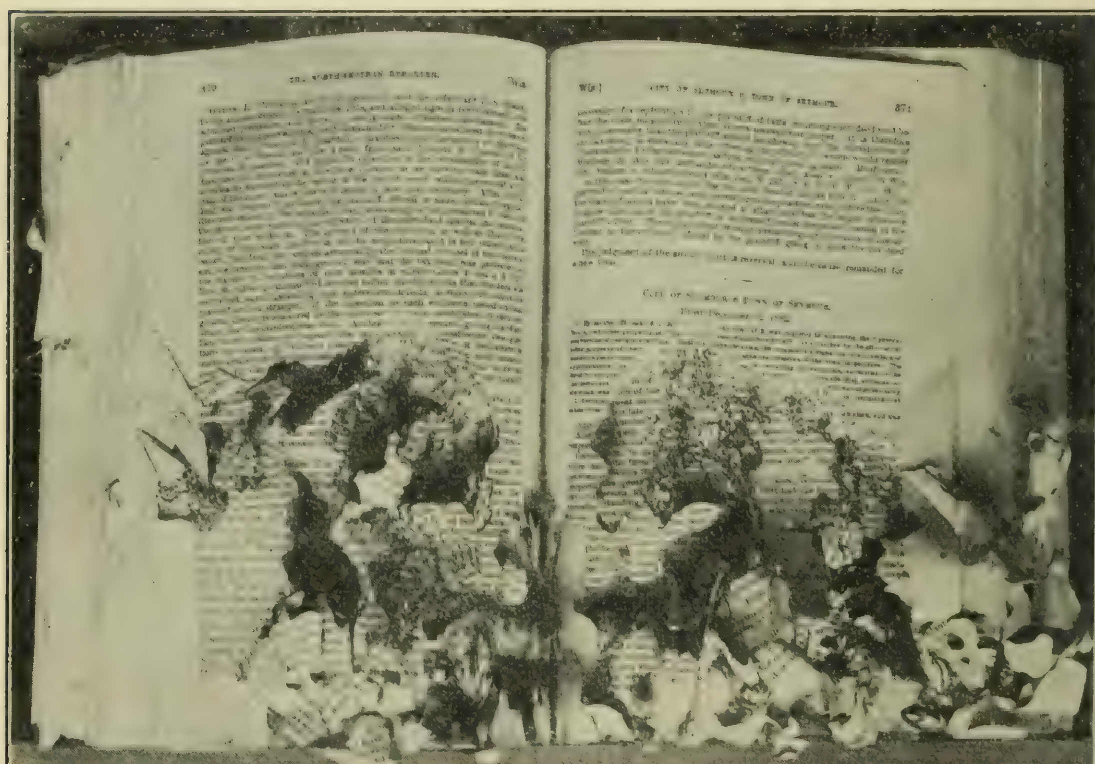

FIG. 16.—A book from an Arkansas library, ruined by the feeding of termites. (*From U. S. D. A. Farmers' Bull.* 759.)

In a somewhat different way the silverfish (Fig. 95) usually establishes itself in new quarters before it is suspected, because it is nocturnal and hides in cracks during the daytime. It has a fondness for starchy material and glue, which leads it to eat at book-bindings, photographs, wall-paper and all kinds of labels. A most annoying case of damage by these creatures recently came to our attention. In a large engineering laboratory it was discovered that the silverfish, in order to get the sizing in the paper, had effaced the numbers on inventory cards that gave the only clue to valuable apparatus out on loan.

Everyone has had the discomfiting experience of finding that furs, rugs, upholstered furniture, and winter clothing stored during the

summer, have been so eaten by clothes moths as to render them useless (Fig. 17). A few insects have the surprising habit of feeding upon such things as drugs and tobaccos. The tobacco beetle riddles cigars and cigarettes with fine holes (Fig. 18). It also does great damage to upholstered furniture and in wholesale houses sometimes causes losses by tunneling through the leather soles of boots and shoes. The drug-store beetle is most catholic in its tastes, having been found feeding in at least 45 different kinds of drugs, some of which are poisonous to man, and also on such widely different articles as books, sheet cork, chocolate, red and black pepper, ginger, and yeast cakes.

Conclusion

It has been seen how widespread and diverse is the conflict between insects and man. Our growing crops must struggle against insect attacks from the time the

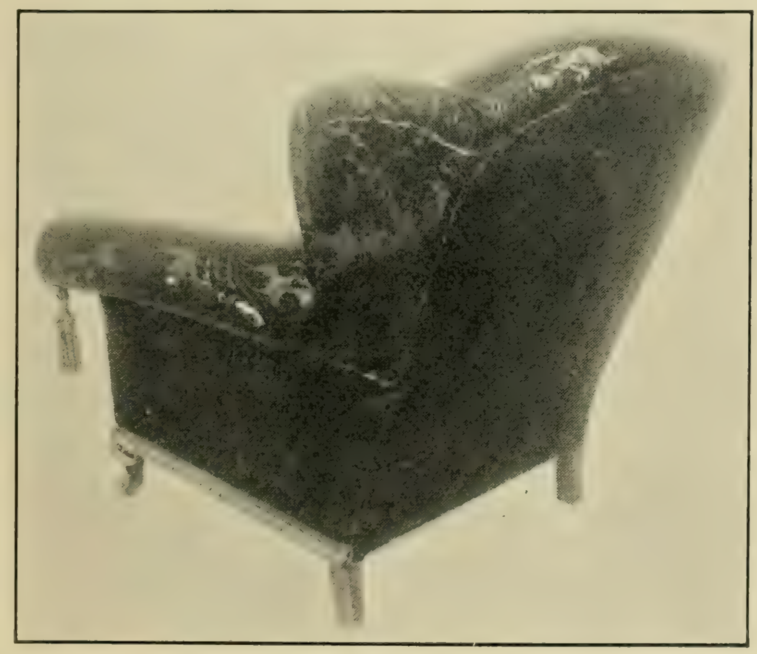

Fig. 17.—Overstuffed winged chair damaged by clothes moths. The bare spots were caused by the moths eating beneath the cover, resulting in the falling out of the mohair pile. (*From Back and Cotton, U. S. D. A.*)

Fig. 18.—Cigar ruined by the feeding of the tobacco beetle. (*Original.*)

seed is planted until the crop is safely harvested—attacks upon leaves, branches, stems, roots, buds, blossoms, and fruits. Our domesticated animals, and man himself, are harassed and bitten and worried and their bodies infested with maggots and inoculated with disease. Our foods are contaminated, our clothing ruined, our books and papers consumed, the wires that carry our messages rendered ineffective, and the timbers of our houses eaten piecemeal.

No one knows how much better off man might be were all his insect enemies destroyed. We can only conjecture, and by piecing together scattered records from many individuals of authentic losses, arrive at estimates of the total. Such an attempt to indicate what our insect enemies cost us is given in Table II. These estimates are based on the commonly accepted belief that insects destroy, on the average, and the country over, at least 10 per cent of every crop grown every year. We wish it to be understood that while these estimates are widely accepted, we are not responsible for them except as they are applied to the crop statistics for the particular year.

TABLE II.—THE INSECTS OF THE UNITED STATES IN ACCOUNT WITH THE AMERICAN PEOPLE

Debit

Most Important Items for the Year 1924[1]

Damage to:			
2,436,513,000 bu.	Corn Crop	$240,546,800	
872,673,000 bu.	Wheat Crop	113,659,600	
1,541,900,000 bu.	Oats Crop	73,949,500	
292,726,000 bu.	Barley, Rye, Rice Crops	24,389,300	
112,450,000 tons	Hay Crop	146,764,800	
977,000 bu.	Cloverseed Crop	1,336,200	
105,619,000 bu.	Grain Sorghums Crop	9,935,300*	
32,001,000 gal.	Sorghum Syrup Crop	2,759,500*	
6,893,000 tons	Sugar Beet Crop	4,989,000*	
636,462,000 lb.	Peanut Crop	4,307,800*	
4,476,000 tons	Cottonseed Crop	20,553,800*	
10,081,000 bale	Cotton Crop	156,334,700*	
1,474,786,000 lb.	Tobacco Crop	29,893,600*	
Total estimated damage to staple crops by insects			$ 829,419,900
Damage to:			
454,784,000 bu.	Potato Crop	$ 29,486,100	
71,861,000 bu.	Sweet Potato Crop	9,229,000	
15,740,000 bu.	Bean Crop	5,748,000*	
7,288,000 bu.	Pea Crop	3,678,900*	
16,318,000 bu.	Onion Crop	2,533,700*	
740,000 tons	Cabbage Crop	1,718,300*	
18,845,000 bu.	Vegetable Seeds Crop	2,500,000*	
Sweet Corn, Tomatoes, Melons, Cucumbers, Asparagus, Hops, and Other Truck Crops		10,000,000*	
Total estimated damage to vegetable crops by insects			$ 64,894,000
Damage to:			
179,443,000 bu.	Apple Crop	$ 21,219,300	
51,679,000 bu.	Peach Crop	6,591,400	
17,961,000 bu.	Pear Crop	2,528,700	
16,500,000 boxes	Orange Crop	8,415,000*	
8,000,000 boxes	Other Citrus Fruits	3,750,000*	
Total estimated damage to fruit crops by insects			$ 42,504.400

[1] In the case of the items starred (*), estimates are for the latest year available.

TABLE II.—(*Continued*)

Damage to:		
$61,892,000 Flowers and Flowering Plants.......	$ 6,189,200	
$15,487,000 Vegetables and Vegetable Plants grown under glass...............	1,548,000	
Total estimated damage to nursery and greenhouse products................................		$ 7,737,200
Injury to:		
18,263,000 head of Horses....................	$ 11,762,000	
5,436,000 head of Mules....................	4,576,000	
66,801,000 head of Milk Cows and Cattle......	106,452,000	
38,361,000 head of Sheep....................	3,020,000	
65,301,000 head of Hogs....................	6,371,000	
654,200,000 head of Chickens..................	8,208,000*	
Total estimated loss in livestock production by insects................................		$ 140,389,000
Total estimated damage to all products in storage................................		300,000,000*
Total estimated damage to forest trees and forest products................................		130,000,000*
Injury by transmission of Malaria by Mosquitoes................................	$ 50,000,000*	
Injury by transmission of Typhoid Fever, Tuberculosis, Enteritis, Diarrhea, etc., by House Flies	25,000,000*	
Injury by transmission of Spotted Fever by the Tick................................	100,000*	
Total economic loss by insects that carry human diseases................................		$ 75,100,000*
Grand total................................		$1,590,044,500

CHAPTER II

THE VALUE OF INSECTS TO MAN

So much of the writings about insects must necessarily deal with their destructiveness that we may be in danger of forgetting that many insects have beneficial attributes and habits the value of which we can hardly overestimate. It is a little startling to discover that this humble class of animals contributes to the world's commerce products that sell for more than $125,000,000 each year, in the United States alone;[1] or to read from the pen of an American entomologist[2] that:

> Except for the check put upon insect multiplication through warfare within the insect household, by which one species of insect destroys its relatives, no informed naturalist would expect the survival of the human race for a longer period than 5 to 6 years. Not only would man's food supply be appropriated by his insect enemies, but it would be impossible for him to withstand the withering march of malaria, yellow fever, typhoid, bubonic plague, sleeping sickness, and other maladies transmitted by insect carriers.

In this we see an important reason for studying these creatures very carefully, in order that we may be able to distinguish insect friend from insect enemy. Almost any entomologist can tell from his own experience of incidents where farmers have gone to great trouble and expense to destroy quantities of insects, only to learn later that the insect destroyed was not only harmless but was actually engaged in saving his crops by eating the destructive form. Certainly most entomologists have had correspondents send in the larvæ of Syrphidæ or lady beetles with the complaint that they were injuring plants; at the same time overlooking the smaller aphids which were causing the injury and which these larvæ were continually devouring.

Each citizen owes it to himself to know, as well as possible, the sundry ways in which beneficial insects affect the complex currents of plant and animal life to his advantage. The curious facts of honey production, silk production, and shellac production; the wonderfully intricate mechanisms of pollinization; the nature of the food, and the means of getting it, of insectivorous game, fur-bearing animals, fish, fowl, and songbirds, which subsist so largely on insect food; the possibilities of

[1] See "Yearbooks," U. S. Dept. of Agr.; statistics on silk, honey, beeswax, shellac, etc.

[2] Gossard, H. A., "Relation of Insects to Human Welfare," *Jour. Econ. Entomol.*, Vol. 2, pp. 313–32, October, 1909.

greatly increasing the quantity of certain fish and game, at present only a delicacy on the tables of the wealthy (or the lucky!); the overwhelming possibilities for human ill or welfare leashed in the prodigious hordes of bugs that eat each other—all these things are entomological topics that deserve our earnest consideration.

THE WAYS IN WHICH INSECTS ARE BENEFICIAL OR USEFUL TO MAN

A. *Insects produce and collect useful products or articles of commerce:*

1. The secretions of insects are valuable:
   (*a*) The saliva of the silkworm is the true silk of commerce.
   (*b*) Beeswax is a secretion from hypodermal glands on the under side of the honeybee's abdomen.
   (*c*) Shellac is the secretion from hypodermal glands on the back of a scale insect of India.
   (*d*) The light-producing secretion of the giant firefly of the tropics is used in minor ways for illumination, and may point the way to the synthesis of a substance giving brilliant light with almost no accompanying heat.
2. The bodies of insects are useful or contain certain useful substances:
   (*a*) Cochineal and crimson lake are pigments made by drying the bodies of a cactus-scale insect of the tropics.
   (*b*) Cantharidin is secured from the dried bodies of a European blister beetle known as the "Spanish fly."
   (*c*) Extracts from the bodies of honeybees and cockroaches are used to some extent as medicine.
   (*d*) Insects, such as the hellgrammite or dobson, are widely used as fish bait, and the best artificial flies are modeled after insects.
3. Insects collect, elaborate, and store plant products of value:
   (*a*) Honey is nectar assembled from blossoms—concentrated, modified chemically, and sealed in waxen bottles by the honeybee.
4. Insects cause plants to produce galls, some of which are valuable:
   (*a*) Tannic acid from insect galls has been used for centuries to tan the skins of animals for leather or furs.
   (*b*) Many insect galls contain materials that make the finest and most permanent inks and dyes.

B. *Insects aid in the production of fruits, seeds, vegetables, and flowers, by pollinizing the blossoms:*

1. Most of our common fruits are pollinized by insects. The growing of Smyrna figs is dependent upon a small wasp that crawls into the flower cluster.

2. Clover seed does not form without the visit of an insect, usually some kind of a bee, to each blossom.

3. Peas, beans, tomatoes, melons, squash, and many other vegetables require insect visits before the fruits "set."

4. Many ornamental plants, both in the greenhouse and out-of-doors, are pollinized by insects; for example, chrysanthemums, iris, orchids, and yucca.

C. *The bodies of insects serve as food for many animals that are valuable to us:*

1. Many of our food fish subsist largely upon aquatic insects.

2. Many highly prized song and game birds depend upon insects for a large percentage of their food.

3. Chickens and turkeys naturally feed upon insects and, under proper conditions, can be raised almost exclusively on such a diet.

4. Hogs may feed and fatten upon white grubs rooted from the soil.

5. A few of the wild, fur, and game animals eat insects; for example, skunk and raccoon.

6. In many parts of the world, from ancient times to the present day, insects have been eaten extensively by human beings. Grasshoppers, crickets, walking sticks, beetles, caterpillars and pupæ of moths and butterflies, termites, large ants, aquatic bugs, cicadas, bee larvæ and pupæ, are prized as food by most of the more primitive races of men.

D. Many insects destroy other injurious insects:

1. As parasites, living on or in their bodies and their eggs.
2. As predators, capturing and devouring other insects.

E. Insects destroy various weeds.

F. Insects improve the physical condition of the soil and promote its fertility:

1. By burrowing throughout the surface layer.
2. Their dead bodies and droppings serve as fertilizer.

G. Insects perform a valuable service as scavengers:

1. By devouring the bodies of dead animals and plants.
2. By burying carcasses and dung.

H. Certain insects are indispensable in scientific investigations:

1. The ease of handling, rapidity of multiplication, and low cost of keeping and rearing have made the pomace fly invaluable in the study of genetics.

2. Studies of variation, geographical distribution, and the relation of color and pattern to surroundings have been greatly advanced through the study of insects.

3. Principles of regeneration and parthenogenesis have been discovered by the study of insect physiology.

4. The behavior and psychology of higher animals has been illuminated by a study of the reactions of insects, whose behavior can be analyzed into very simple tropisms. Valuable lessons in sociology have been deduced from a consideration of the economy of social insects.

I. Insects have æsthetic and entertaining value:

1. Their shapes, colors, and patterns serve as models for artists, florists, milliners, and decorators.

2. The more highly colored and striking forms are much used as ornaments in trays, pins, rings, necklaces, and other jewelry.

3. Moths and butterflies are universally admired, while those who use the microscope find much to admire in the colors and patterns of many of the smaller insects.

4. The songs of insects have been found highly interesting.

5. Insects have served as subject matter for hundreds of poems.

6. The inimitable variety found among insects, and their curious habits, afford entertainment and diversion for thousands who collect and study them.

7. The Orientals gamble on crickets trained for fighting.

Useful Insect Products

The most obvious and tangible of the benefits that arise from insect activities is the utilization of the things that insects make, collect, or produce.

Silk.—Preeminent among insects valuable in this way is the silkworm. Very few persons know the silkworm by sight, but everyone knows the product it manufactures. Those who use this product

most, seldom, if ever, think of its lowly origin; many doubtless do not know that silk is caterpillars' spittle.

The parent of the silkworm is a creamy white moth (Fig. 19) about 2 inches across the open wings. It is fat bodied and feeble winged; it scarcely ever flies; it takes no food and lives only 2 or 3 days, but long enough to mature and lay 300 or 400 eggs. This insect has been a creature of domestication from time beyond memory and history, a captive and slave to man. For more than 35 centuries it has toiled ceaselessly for man; countless generations laying their eggs, eating the mulberry leaves provided for them in the larval stage, spinning their

Fig. 19.—The parent or moth stage of the silkworm, about natural size. Male above, female below. (*From Slingerland.*)

cocoons, and then dying—a perpetual sacrifice to man's and woman's demand for adornment. For more than 2,000 years, only the Chinese people knew where silk came from. They punished with death anyone who tried to take the eggs or silkworms out of their country, and it is said that this material was sometimes valued at its weight in gold. But in the year 555 A. D., two monks were sent as spies to China and brought back to Constantinople some eggs of the silkworm moth concealed in a staff that they carried. In this humble way, silk culture was introduced into Europe.

Silkworms are the larvæ, or "worm stage" of the moth, *Bombyx mori* Linn. They hatch from the eggs laid by the moth and in 3 or 4 weeks have grown to fat caterpillars about 3 inches long (Fig. 20). Then comes the marvelous metamorphosis that converts the caterpillar into a moth like its parents. That this transformation might take place most safely, the last act of the larva is to enclose itself in a silken house.

This house is constructed out of a curious saliva that hardens at once upon exposure to the air to form soft delicate threads of remarkable strength and pliability. These silken threads are formed by a silkworm at the average rate of about 6 inches a minute. The house building or cocoon making occupies 3 days. When its cocoon is completed, the larva changes to a pupa or chrysalid, which, if allowed to live, transforms to a moth 2 or 3 weeks later. When the moth is fully developed and ready to emerge, it secretes an alkaline fluid that softens one end of the cocoon, and breaking the strands of silk, it squeezes out—a soft, feeble, crumpled adult.

The substance that is so skilfully wound together to make the cocoon is produced from true salivary glands (Figs. 54, *sg* and 81, *sg*) that open through the mouth. All during the growth of the larva, these large glands are being filled with the relatively enormous quantity of fluid necessary to make the cocoon. This secretion has a commercial value

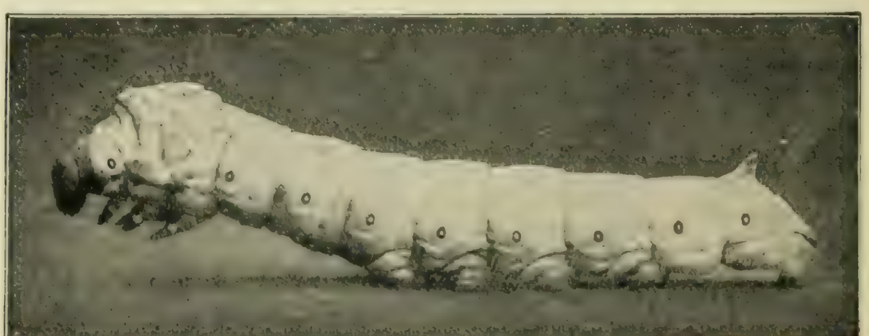

Fig. 20.—The full-grown silkworm (larva) about natural size. (*From "Silk, Its Origin, Culture and Manufacture," courtesy Corticelli Silk Company.*)

of from $200,000,000 to $500,000,000 a year. From 50,000,000 to 70,000,000 pounds of it are marketed each year as raw silk. It requires more than 25,000 cocoons (Fig. 21) to make a pound of silk. The production of this vast quantity of silk floss, therefore, is accompanied by the sacrifice of the lives of billions of caterpillars.

Each cocoon is composed of a single, continuous thread commonly averaging about 1,000 feet in length. If the moth were allowed to emerge, this single, unbroken thread would be dissolved and broken into hundreds of tiny, useless pieces. The silk grower needs comparatively few moths to provide a new stock of eggs. He does need millions of cocoons. The other cocoons must be saved from injury by the moth. Accordingly, about 10 days after they have made their cocoons, the caterpillars or their pupæ are killed by dropping the whole lot into hot water, by steaming them, by dry heat, or by fumigation. The cocoons are then assorted according to color and texture, the loose outer threads removed, the cocoons soaked in warm water to soften the gum that

binds the silk threads together, and skilfully unwound by expert operators. The threads from several cocoons are wound together onto wheels to form the reels of raw silk. Subsequently, the raw silk is boiled, scoured, steamed, stretched, purified by acids or by fermentation, washed and rewashed, to remove the gum and bring out the much-prized luster; and finally, combed and untangled, it is ready for spinning into the beautiful fabrics that eventually appear upon the market to beautify our homes and adorn our bodies.

Many kinds of moths (and insects of some other orders) thus spin cocoons for the protection of the pupa stage (see Fig. 85). But one species chiefly is cultivated for this purpose, largely because of the ease with which the larvæ and adults are handled and kept captive and the

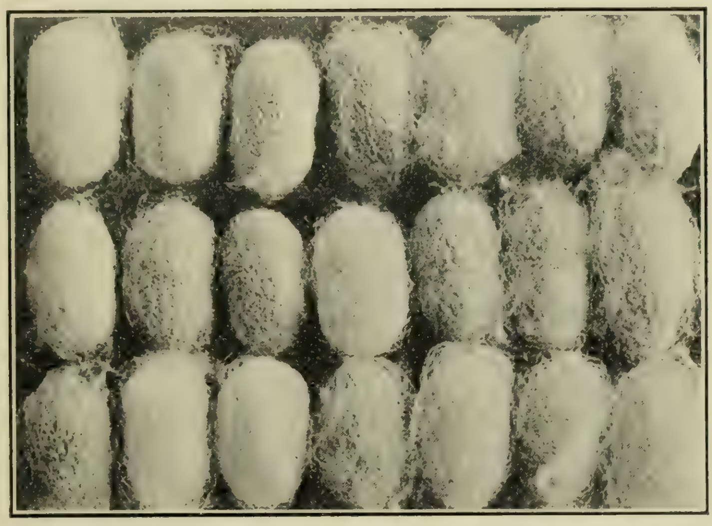

FIG. 21.—Cocoons of the silkworm from which the true silk of commerce is unwound, about one-half natural size. (*From Garman, Ky. Agr. Exp. Sta.*)

readiness with which this particular cocoon can be unwound. Sericulture has been given serious study and is an important industry in Italy, France, Spain, China, and Japan, where the silk-growing peasants rear, feed, and tend these worms from eggs to cocoons as carefully as farmers in America rear sheep, cattle, hogs, or poultry. The chief reason that silk growing is not followed in America is that the higher cost of American labor does not enable us to compete with the Orient.

Honey.—Man has domesticated many kinds of animals and directed their activities so that the products resulting from their life processes might be available for his use. Of the many species of insects only two, the silkworm and the honeybee, have been domesticated. These are so remarkably successful that one wonders if there are not many other kinds that could be domesticated with profit.

Many kinds of bees and wasps store honey as food for themselves and their young. But here again, as with the silkworm, only one species of outstanding merit has found a place in the husbandry of man.

FIG. 22.—A bit of honeybees' comb in section, showing the waxen bottles in which honey is being stored and which serve also as cells for the protection of the egg, larval, and pupal stages of the bees. Note the two eggs and the partly grown larva. Above at left a field bee is transferring her load of nectar to a hive bee. At the right a hive bee is ripening the nectar by forcing it in and out of her mouth. (*After Park, in Jour. Econ. Entomol.*, Vol. 18.)

In this case, the insect is not the primary benefactor to the same degree in which the silkworm is. It does not make the raw product, but is only an intermediary between honey-bearing plants and the human race. Plants secrete nectar in profusion, but in such numerous and infinitesimally small portions that man unaided could never afford to collect it. It requires from 40,000 to 80,000 trips of a honeybee, and visits to many times this number of flowers, to find and assemble nectar enough to make a pound of honey. The average trip is thought to be about 1 or 1½ miles. Hence, for a single bee to collect nectar enough for 1 pound of honey would mean traveling at least twice the distance around the world.

Driven by an instinct to provide for their young and to fortify themselves against times of want, and operating in almost countless numbers, day after day, trip after trip, bit by bit, the bees gather these sugar-bearing secretions of plants and store their treasures in minute waxen bottles of their own making. In this way 200,000,000 to 400,000,000 pounds of this product are collected and stored annually in the United States. Billions of pounds of nectar go to waste each year for want of enough bees to gather it.

While the bees cannot be said to manufacture this product, their contribution is not solely that of harvesters. The nectar that is swallowed undergoes some chemical change due to intermixture with the saliva.[1] Some ingredients of the bees' own elaboration are probably added to the secretions of the plant and the large and variable water content of the different nectars is greatly reduced.

The nectar obtained from flowers, after being mixed with saliva and swallowed, is carried in the honey sac (crop) until the bee reaches the hive. The honey sac is a kind of first stomach surrounded by muscles and provided with valves so arranged that its contents may be passed on into the stomach or, by compression, emptied back through the mouth parts into the cells of the hive (Fig. 22). The nectar is concentrated by evaporation of a large part of its water content in a strong current of air produced over the cells by the rapid beating of the wings of the worker bees. When a cell is filled with properly "ripened" honey, it is capped over with wax and appears in the form familiar to everyone as comb honey. Nectar or honey forms the principal food of adult and larval bees.

Beeswax.—The life processes of the honeybee also give us the useful material known as *beeswax*. Besides forming the cells in which the honey is stored, and serving as "cradles" for the bees during their development (Fig. 22), beeswax is extensively used in many arts and trades. From 12,000,000 to 15,000,000 pounds of it, worth several

[1] Saccharose (cane sugar) is changed to glucose (grape sugar) and levulose (fruit sugar). These "invert" sugars are more readily assimilated by man.

million dollars, are used in the United States each year. This material is a natural secretion of the worker bees that is poured out in thin delicate scales or flakes on the underside of the abdomen (Fig. 23). Its production directly follows the digestion of a quantity of honey, a pound of wax resulting from the consumption by the worker bees of from 3 to 20 pounds of honey in about 24 hours' time.

FIG. 23.—Scales of wax on the ventral side of the abdomen of the honeybee. Beeswax is a secretion from hypodermal glands that open through the cuticula of the bee. (*From H. F. Wilson.*)

Shellac.—A tiny species of scale insect (related to our fruit pest, the San José scale) yields the substance from which shellac is made. This substance is extensively used in making varnishes and polishes, for finishing woods and metals; for stiffening hat materials; as an ingredient of lithographic ink; as sealing wax; as an insulating material in electrical work; and in making phonograph records, airplanes, linoleum, buttons, shoe polishes, pottery, toys, and imitation fruits and flowers. That this substance is derived from an insect is realized by very few persons.

The lac insect, *Tachardia lacca* Kerr (Fig. 24), lives on native forest trees in India. The natural function of the lac is to protect the motionless insect from adverse weather and natural enemies. On contact with the air the resinous secretion hardens, and where the insects are closely crowded together it forms a continuous layer over the branches (Fig. 24, *A*). In this condition the substance is known as *stick lac.*

About 40,000,000 pounds of stick lac are collected annually. It is ground in crude, hand-operated mortars and the resulting material separated into (*a*) granules of lac known as *seed lac*, (*b*) dust, which is used to make toys, bracelets, and bangles, and (*c*) wood which is used as fuel. The seed lac is next soaked in water and treaded by foot, which

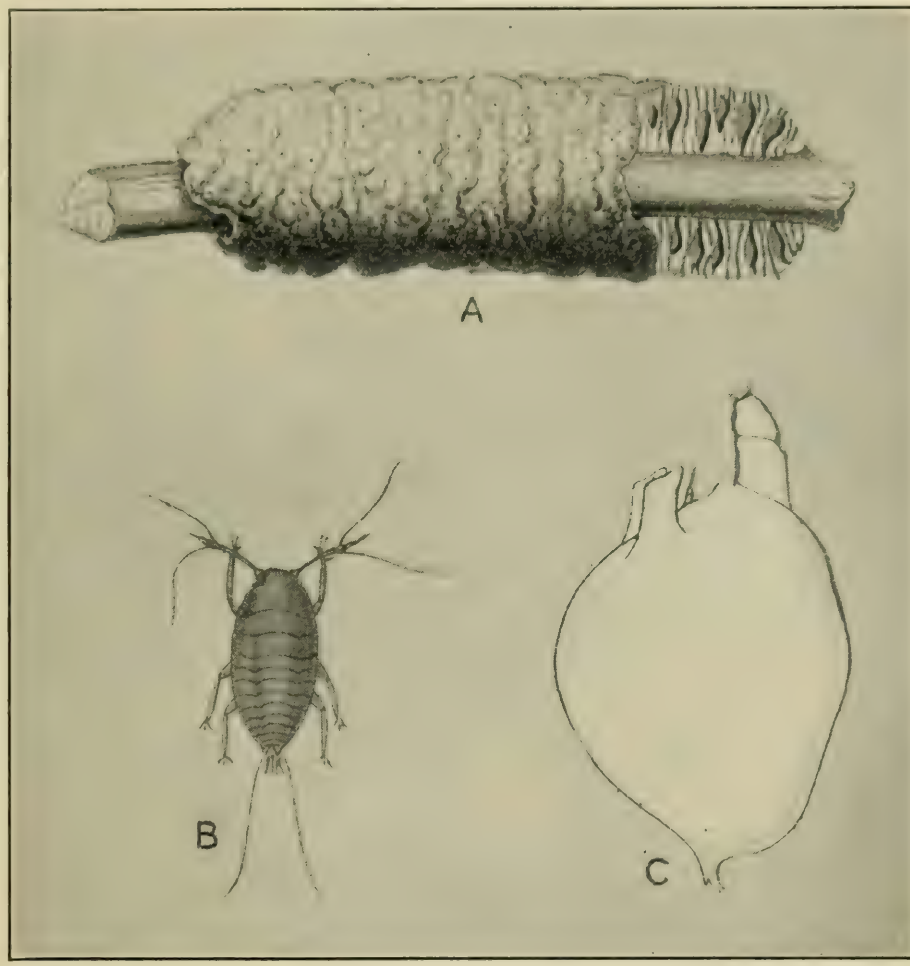

FIG. 24.—The lac insect. *A*, a piece of twig thickly encrusted with lac. The part on the right is broken open to show the worm-like lac insects in their cells. Each living insect communicates with the exterior through three small apertures, shown on the surface of the encrustation. (About natural size.) *B*, the young lac insect (first instar nymph or "crawler") greatly enlarged. *C*, the body of an adult female lac insect, freed from its resinous secretions, as seen from the side. At the upper end is the segmented abdominal extremity of the insect, terminating in the fringed anus. At the left is the dorsal spine and overhanging it the two respiratory processes which guard the spiracles. The mouth parts are at the lower extremity and, during life, inserted in the bark. About twelve times natural size. (*Modified from Green, "Coccidæ of Ceylon."*)

crushes and washes out the wine-colored pigments that were formerly sold as dyes but no longer have any commercial value. The granular lac, after drying and bleaching in the sun, is placed in slender cloth bags, 10 or 12 feet long, heated by open charcoal fires, and, by the twisting of the ends of the bag, is forced out as it melts, and drops upon the floor (Fig. 25). Before these pads of melted lac have had time to

congeal, they are grasped by natives who stretch them with their hands, teeth, and feet to extremely thin sheets.[1] After drying, these sheets are broken into thin, small flakes; in this condition they are shipped. Dissolving the flake lac produces the familiar white or orange liquid shellac.

The lac industry is an ancient one, certainly several thousand years old. The material has been used as a varnish at least since 1590. The insect is not domesticated nor even cultivated, but lives in such abundance on the forest trees that millions of the poorer classes of India

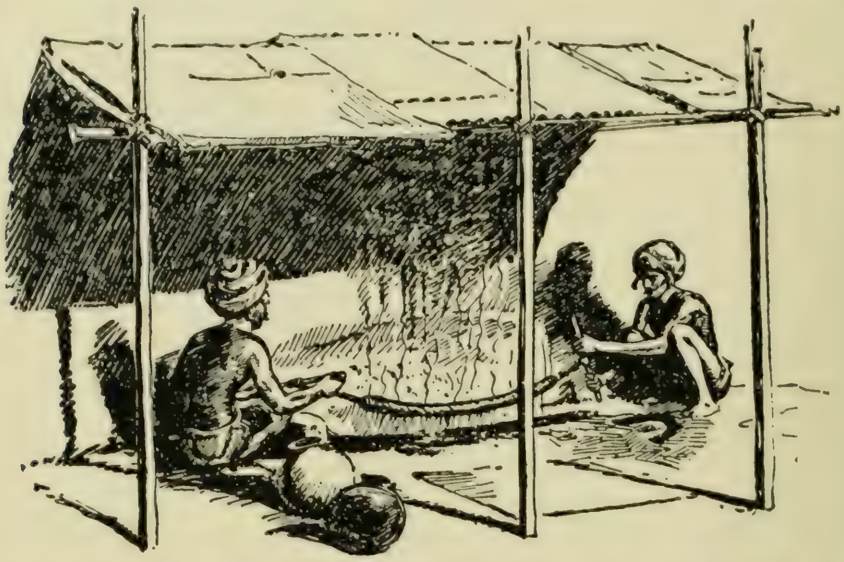

FIG. 25.—Indian natives melting lac. One step in the preparation of shellac for the market. (*From "Shellac: A Story of Yesterday, Today, and Tomorrow," courtesy James B. Day & Co.*)

find in this industry their sole means of livelihood. No superior modern substitute has been found. From $10,000,000 to $20,000,000 worth of this product is used in the United States each year. Of late, extensive fluctuations in the abundance of the insect have led to the suggestion of simple routine methods of manipulation intended to reduce the extent of parasitism and increase the "set" of young insects on the host trees; and machine methods are now being used to some extent in producing the lac. Doubtless many other improvements will be initiated from time to time as the demand for the product makes necessary a more economical method of production. Recently a synthetic lacquer has been produced which will doubtless supplant the true shellac for many purposes.

Light without Heat.—One of the most remarkable phenomena in nature is the property that many animals possess of emitting light, "*phosphorescence.*" This phenomenon is known among the Protozoa, Coelenterata, Mollusca, Annelida, fishes,

[1] See "Shellac: A Story of Yesterday, Today and Tomorrow," James B. Day and Company.

birds, Crustacea and others, but doubtless the best-known examples are among the beetles, commonly known as fireflies or lightning-bugs.[1] (See Fig. 125.)

The substance that gives rise to the light rays is not phosphorus but has been called *luciferin*. It is formed in certain specialized cells of the insect body. These cells are abundantly supplied with tracheæ or breathing tubes. When air is admitted under the control of the insect, the combustion of the luciferin takes place in the cells that produce it and the production of light is instantaneous. The insect body is generally provided with a reflector for the light, formed by a white material (probably ammonium urate), secreted by the cells directly behind the photogenic tissues.

The light emitted by our fireflies is most remarkable in having the maximum of visibility (from 92 to nearly 100 per cent light rays) and practically no heat rays or ultra-violet rays. In the ordinary gas flame, by contrast, only 2 per cent of the energy is converted into light rays, the rest being lost as low heat rays; in the electric arc only 10 per cent of the energy produces light; while sunshine is only 35 per cent light.

Some slight use has been made of these light-giving insects as ornaments, as an artificial illuminant, and in photography. But the significant benefit we may hope to derive from them is guidance to the synthesis of a luciferin in the chemical laboratory which may give to the world an artificial illuminant many times as efficient as the best artificial lights of the present day.

Cochineal.—Cochineal, a beautiful carmine-red pigment or paint, is the dried, pulverized bodies of a kind of scale insect (*Coccus cacti* Linn.), that lives on the prickly pear (*Opuntia coccinellifera*). Cochineal is now used principally as a cosmetic or rouge; for decorating fancy cakes; for coloring beverages and medicines; for dyeing where unusual permanence is desired; and, because of its property of allaying pain, for treating whooping cough and neuralgia.

It was known and used by the Aztecs in Mexico before the discovery of America, and until the aniline dyes came on the market was a very important product. The cochineal insect is now cultivated principally in Honduras and the Canary Islands, though still a product from Mexico, Peru, Algiers, and Spain. The insects are carefully cultivated. The Mexicans keep them indoors over winter on branches cut in the fall from the prickly pear. In spring, they put the females out in little straw nests fastened to the cacti. The young bugs settle on the cactus and in 3 months' time the cochineal insects are fully developed and ready to harvest. The branches are broken off, the insects brushed from them into bags and killed by hot water, steam, dry heat, or drying in the sun. The impurities are then removed and the product is ready for the market. It requires about 70,000 insects to make a pound of cochineal.

Insects as Medicine.—Many kinds of insects have been reputed to possess medicinal properties. In fact, during the seventeenth century some curative power was attributed to almost every known insect. At that time the belief prevailed that every creature possessed some special usefulness to man. No other virtue being apparent for many of the insects, special therapeutic qualities were ascribed to them.[1] Of course, the vast majority of such recommendations are pure quackery and are founded on the rankest of superstition. Examples are the reputed belief that the bite of a katydid or cricket will remove warts; that cockroaches, crickets, or earwigs, variously bruised, burned, or boiled and properly compounded and applied, will cure earache, weak sight, ulcers, and dropsy.

Certain insects, however, do have a real medicinal value, notably the honeybee (*Apis*) and blister beetles. The best known of the blister beetles is the so-called Spanish fly (*Lytta vesicatoria* Linn.) that occurs in great abundance in France and Spain. This is a relative of our American blister beetles or "old-fashioned potato beetles." These insects have in their blood and internal organs a substance known

[1] The phosphorescent insects belong in the genera *Photinus* and *Lampyris* of the family Lampyridæ and in the genus *Pyrophorus* of the family Elateridæ.

as *cantharidin* ($C_{10}H_{12}O_4$). It was formerly greatly used as an external local irritant or blister. Lloyd[1] says that "the barbarisms practiced upon the American people during the nineteenth century by the application of cantharis blisters for all sorts of ailments, overtopped the misery endured by those who suffered in the war of the Revolution." This material was also much used as an aphrodisiac before its dangerous nature was appreciated. At present it has a place as an internal treatment in certain diseases of the urino-genital system and in animal breeding.

While the use of cantharidin appears to be dying out, the use of *Apis* as a pharmaceutical preparation of recognized merit has increased in the past century. The preparation known as "specific medicine Apis" is extracted from the bodies of honeybees by killing them in alcohol while they are intensely excited, and digesting their bodies in this medium for a month at a warm temperature. It is finally brought to a strength representing 2 ounces of bees to 1 pint of the medicine. In 1858, this preparation was said to be the most universally useful remedy next to aconite. It is used by many physicians for the treatment of "hives," diphtheria, scarlet fever, erysipelas, dropsy, urinary irritation, and all kinds of œdema accompanied by swelling and burning.[1]

Use of Insect Galls.—The injury to plants by insect galls was discussed in Chap. I. These galls contain certain valuable products that have been used in a variety of ways. Many superstitions have attached to these remarkable growths on plants.[2] However, certain galls are reputed to have genuine medicinal or curative properties. The Alleppo gall, or gall nut, of western Asia and eastern Europe has been used in medicine since the fifth century B.C. It is a powerful vegetable astringent, tonic, and antidote for certain poisons.

Other galls have been used as dyes. The African Somali women use them as a tattooing dye. The Turks secure a fine scarlet color from a reddish gall on oak. Turkey red is dyed from the "mad apple" in Asia Minor. The ancient Greeks used the Alleppo gall for dyeing wool, hair, and skins; more recently great quantities of it[3] have been used in dyeing leather and seal skins. Tannic acid occurs in high percentages (30 to 70 per cent) in many of these galls, which are the richest of all sources of this material.

Galls are used in the preparation of very durable and permanent inks. In some countries the laws require that certain records be made with ink compounded of gall nuts.

Insects as Pollinizers

The maintenance of plant life generation after generation may be accomplished by *asexual reproduction* (the formation of buds, bulbs, and tubers), or by *sexual reproduction*, in which one specialized reproductive cell, the male gamete, unites with another, the female gamete, and from this union a new individual arises. In the higher plants, sexual reproduction is made possible by the process known as pollination. The essential carrier of the pollen from the anthers of one flower to the stigma of another is, in most cases, either the wind or an insect. Well-known examples of wind-pollinated flowers are corn, wheat, and other

[1] Lloyd Brothers, *Drug Treatise* No. XXI, Cincinnati, Ohio.

[2] See Fagan, Margaret M., "The Uses of Insect Galls," *Am. Naturalist*, Vol. 52, pp. 155–176, 1918.

[3] In 1914, $17,000 worth was imported to the United States from Bagdad.

cereals, nut trees, willows, oaks, pines, etc. Wind-pollinated plants generally have flowers that are small and inconspicuous, with poorly developed petals, unisexual flowers, dry, light pollen, and brushlike stigmas.

Most of our fruits and ornamental flowers, many of our vegetables such as beans, peas, tomatoes, melons, squash, and such field crops as clover, buckwheat, cotton, and tobacco depend mainly upon the visits of insects to carry the pollen to the stigma and so make possible a fertilization, without which no seed or fruit would form. Flowers that depend

Fig. 26.—Queens of bumblebees visiting and pollinizing flowers in spring. Seven individuals of three different species are shown: *Bombus americanorum* Fab., lower center; *Bombus separatus* Cress., right center; and *Bombus auricomus* Robt., at right. (*Photo from life by T. H. Frison.*)

upon insects for pollination can be recognized generally by their well-developed corollas of conspicuous size, or by showy colors or a marked odor. They have sticky pollen grains, sticky stigmas, and nectaries that secrete a sweet liquid attractive as food for the insects.

Plants do not develop beautiful blossoms and sweet odors to delight the senses of man. They serve to attract insects. Plants show some remarkable modifications of their structures which compel the insects that come for nectar to carry away with them to the next flowers visited a load of pollen. As they crowd their way in and out of flowers, their bodies become covered with the fine pollen dust. In the honeybee, this is removed from the general body hairs by a highly specialized brush on one of the segments of the hind leg (see Fig. 47, *C*). When the brush

becomes filled, the hind legs are crossed and the pollen grains from one leg are scraped into the pollen basket on another segment of the opposite leg. In the pollen baskets it is carried to the hive, where a spine on the end of the middle leg is used to pry it off and it is stored in the cells. While much of the pollen is thus collected and used as food by the bees, some of it brushes off when the bee or other insect crowds into the next flower visited. Many flowers are so constructed that an insect can hardly get the nectar from them without dusting some pollen from previously visited flowers onto their stigmas. In this way much of the work of fertilizing flowers, without which we should not have much fruit, tomatoes, melons, clover seed, or cotton, is made possible.

Bumblebees (Fig. 26) are worth tens of millions of dollars a year to the American farmer. Farmers generally rely upon the second crop of red clover for the production of seed. Bumblebees are the most important pollinizers of second-crop clover. The honeybee is not important as a pollinizer of red clover because the length of its tongue (see Fig. 72, *D*) is such that it can generally not reach the deep-seated nectary of this flower. The bumblebees winter only as young queens and it takes several months in spring and summer to build up colonies to a point where they are abundant enough to visit every flower head over acres of clover and so make possible the setting of seed. In Australia it was found impossible to obtain seed from red clover until the bumblebees were imported into that country. Certain wild solitary bees[1] have been found also to be efficient pollinizers of red clover. In localities and seasons when these bees are abundant, the first crop of red clover will usually set a large amount of seed, often producing a greater yield than that from the second crop.

Too often the impression prevails that bees are the only insects of importance in cross-pollination. Many kinds of flies, butterflies, moths, and beetles also share in this work. Many of these insects, however, produce injurious caterpillars, grubs, or maggots which may largely offset the benefit derived from the parents. Bees and wasps develop no objectionable progeny. The honeybees can be introduced into any neighborhood, orchard, or garden, and their numbers increased as we wish; or should they no longer be desired, the whole population could be exterminated at will. They are under man's control as no other insect is, except the silkworm. Beekeepers generally believe that the honeybee is worth many times as much, as a pollinizer of our fruits and flowers, as it is for its honey and beeswax. Certain recent experiments confirm this. Fruit growers often rent colonies of bees to be placed in their orchards during the blossoming period.

The Fig Insect.—One of the most striking illustrations of the dependence of plants upon insects is found in the history of the introduction

[1] *Tetralonia* and *Melissoides* spp., Order Hymenoptera, Family Anthophoridæ.

of Smyrna-fig culture into the United States. Previous to 1900, figs grown in this country were of quality and flavor very inferior to those of figs imported from Asia Minor. A careful study of the situation revealed the remarkable fact that the palatability of the Smyrna fig is dependent upon the pollination of the flowers by a small wasp.[1]

A fig is a hollow, pear-shaped receptacle that bears a very large number of minute flowers lining its inner surface. The only entrance

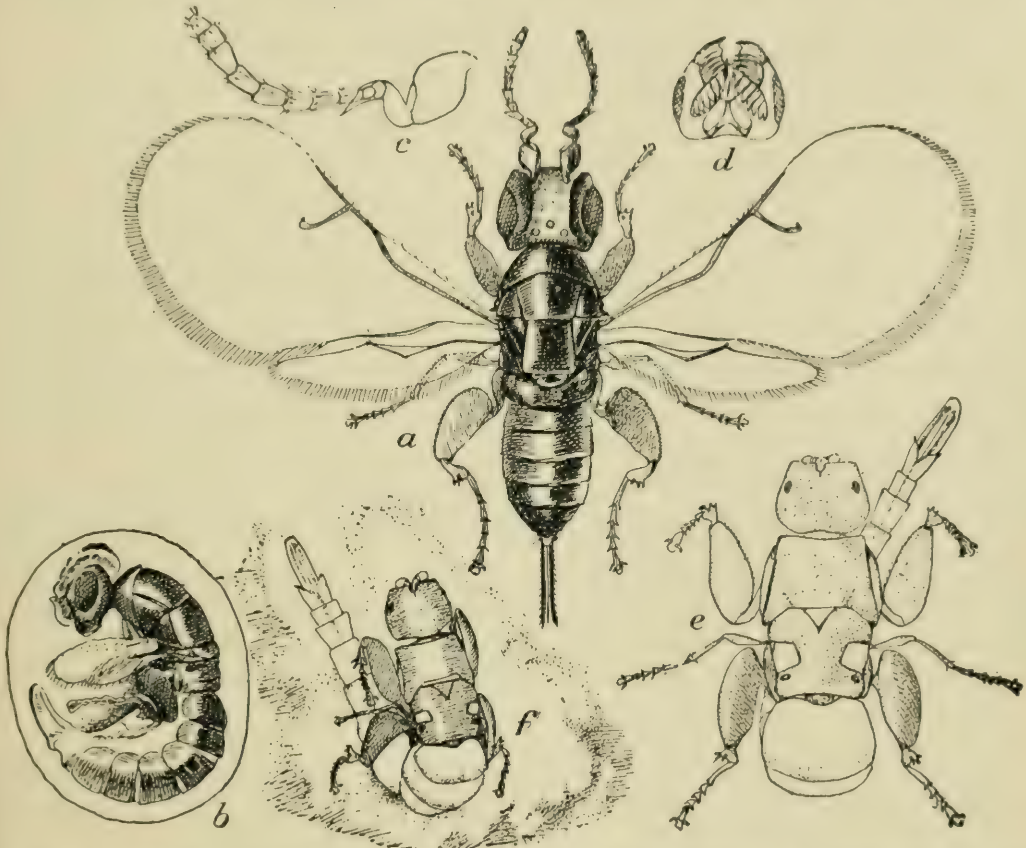

FIG. 27.—The fig wasp. *A*, adult female with wings spread; *b*, female not entirely issued from pupal skin and still contained in gall of the fig flower; *c*, antenna of female; *d*, head of female from below; *e*, and *f*, adult males. All much enlarged; *a*, about 16 times, *f*, about 27 times. (*From U. S. D. A. Dept. Bull.* 732.)

to the flowers is a tiny opening at the free end of the fig. If the flowers are not fertilized, the seeds do not form, and the fleshy, nearly closed receptacle that bears them does not develop the sweet, nutty flavor that characterizes the perfect fruit. The Smyrna fig is exclusively female and produces no pollen. An exclusively male variety, known as the *caprifig*, produces inedible fruits but an abundance of pollen. Pollination is performed only by the female of this tiny fig wasp (Fig. 27, *a*). These insects lay their eggs in the flowers of wild figs, or *caprifigs*, and their larvæ develop in small galls at the base of the caprifig flowers. The males that are formed are wingless (Fig. 27, *e* and *f*) and never leave the wild fig in

[1] *Blastophaga psenes* (Linn.), Order Hymenoptera, Family Chalcididæ (see *Calif. Agr. Exp. Sta. Bull.* 319, 1922, and *U. S. Dept. Agr. Dept. Bull.*, 732, 1918).

which they develop. They crawl about, puncture the galls in which females are developing and fertilize the females through the puncture. After mating, the female gnaws out of her gall, becomes covered with pollen from the stamens of this fig, and then squeezes her way out of the small opening at the free end of the fig and flies about among the trees. In seeking places to lay their eggs, the females enter Smyrna figs as well as the wild figs and although they are said not to lay their eggs in the former, they crawl over the minute flowers and scatter pollen over them from the flowers of the caprifigs in which they developed.

When the part that this minute insect plays in the culture of figs was known, efforts were made to bring some of the wasps from Algeria into California. There were many failures, but a decade of effort finally resulted in the establishment of the insect and the consequent production in America of figs equal to those grown in Asia Minor. It is necessary to grow caprifigs as well as Smyrna figs to keep up the supply of wasps, since the insect does not reproduce in the edible fig. Figs containing mature fig wasps are removed from the caprifig trees, strung on fibers, and suspended among the branches on the Smyrna-fig trees when the latter are ready for fertilization.

Recently the fig wasp has threatened ruin to the fig growers in California by spreading a brown-rot disease to the Smyrna figs from infected caprifigs in which they develop. The little wasps are being reared by millions in sterile incubators and released in the orchards free from brown-rot germs in an attempt to prevent this contamination.

Insects as Food

Although of small size, insects, because of their prodigious numbers, probably exceed in weight all other animal matter on the land areas of the earth. This great mass of material possesses genuine food value. Chemical analyses of white grubs and May beetles, for example, have shown[1] that these insects compare favorably with corn in food value. Turkeys, hogs, and other domestic animals will often fatten on insects.

It has been said that insects make up, on the average, about two-thirds of the food of our common land birds. According to the United States Department of Agriculture,[2] 68 per cent of the food of the bluebird and the chickadee consists of insects and their close relatives. The house wren feeds almost exclusively upon grasshoppers, beetles, caterpillars, bugs, spiders, and their allies. The brown thrasher's food is about 64 per cent insects; that of the meadow lark 74 per cent. More than two-thirds of the food of the downy and hairy woodpeckers is noxious insects, especially those that bore in the trunks of trees. Cuckoos, nighthawks, kingbirds, orioles, swallows, and scores of other kinds eat

[1] *U. S. Dept. Agr. Farmers' Bull.* 940, 1918.

[2] *U. S. Dept. Agr. Farmers' Bull.* 630, 1915.

quantities of insects and feed them to their young. Some game birds also take insects as an important part of their diet. Men are coming to appreciate the value of birds so much that fewer and fewer of them are being killed for food and sport. But it is an extremely happy circumstance that insects are so large a factor in maintaining the lives of such beautiful and delightful creatures as our song birds.

The extensive investigations carried on by Professor Forbes and his associates in Illinois led him to the conclusion, from the examination of over 1,200 fishes from all kinds of Illinois waters, that fully two-fifths of the food of adult fresh-water fishes is insects.[1] Many others that do not feed upon insects during adult life pass through a distinct insectivorous period in their development. Some of the fishes that grow largely at the expense of insect food are: croppies, perch, sheepshead, rock bass, black bass, catfish, red horse, gizzard shad, toothed herring, white and striped bass and certain sunfish. Forbes says:[2]

Without the Entomostraca [small Crustacea] and minute aquatic Diptera of whose very existence the majority of the people are scarcely aware, all our waters would be virtually depopulated.

The insects of most importance as fish food are (*a*) small, slender midge larvæ known as bloodworms,[3] (*b*) May-fly nymphs,[4] and (*c*) caddice worms.[5]

It seems certain that man could make the waters of the earth, which are now very little utilized, produce food materials nearly as extensive and valuable as those secured from an equal area of land. A thorough investigation of the great cycles of plant and animal development taking place in our lakes, streams, and oceans should make it possible to direct them so that enormous quantities of useful products could be harvested. The first step toward this end should be the treatment of all sewage before it is allowed to enter a stream, converting it into forms innocuous to the aquatic life, and admitting it gradually in such quantities as not to overwhelm the organisms in the water. The toxic waste products from manufacturing plants or large quantities of raw sewage should not be permitted to enter a stream.

In many parts of the world considerable quantities of insects are regularly eaten by human beings. These are generally looked upon as great luxuries by the less civilized races. In Mexico the eggs of certain large aquatic bugs are regularly sold in the city markets. The eggs are about the size of bird shot. The Mexicans sink sheets of matting under water upon which the eggs are laid by millions. These are then dried and placed in sacks, sold by the pound and used for making cakes. The

[1] *Bull. Ill. State Lab. Natural History*, Vol. 2, pp. 475–538, 1888.

[2] *Bull. Ill. State Lab. Natural History*, Vol. 1, p. 75.

[3] Order Diptera, Family Chironomidæ.

[4] Order Ephemeroptera, Family Ephemeridæ.

[5] Order Trichoptera.

people of Jamaica consider a plate of crickets a compliment to the most distinguished guest. Ox warbles are eaten raw by the Dog Rib Indians. Natives of Australia collect quantities of the bugong moth (*Agrotis infusa*) in bags and roast them in hot coals, and claim that they taste like nuts and abound in oil. The Indians and semi-civilized natives of many countries catch quantities of ants for food, and generally eat them alive.

From the actions of wild animals and the testimony of those persons who have tried insects as food, it seems that much of this material is palatable. It would, in fact, be difficult to give any sound reasons why we should consume quantities of oysters, crabs, and lobsters, and disdain to eat equally clean, palatable, and nutritious insects. Perhaps the economists of the future, if hard pressed to maintain an ever-increasing population, may well turn their attention to the utilization of certain kinds of insects as human food.

Predaceous and Parasitic Insects

The various benefits from insects enumerated above, although genuine, are insignificant compared with the good that insects do by fighting among themselves. There is no doubt that the greatest single factor in keeping plant-feeding insects from overwhelming the rest of the world is that they are fed upon by other insects. It is easy to see how the industry of insects and their devotion to purpose, when coupled with almost unlimited numbers of individuals, can work a miracle for us when their instincts lead them to seek and devour myriads of pests scattered over a farm or a forest. Man will probably never be able to do as much in controlling his insect enemies as his insect friends do for him.

Fig. 28.—An insect predator: a robber fly with its prey. (*From Howes' "Insect Behavior," courtesy Richard G. Badger.*)

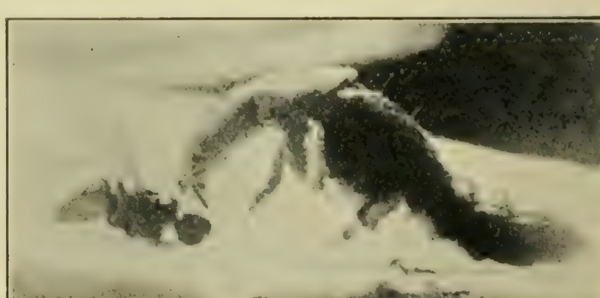

Fig. 29.—An insect predator: a rove beetle devouring a fly. (*From Howes' "Insect Behavior," courtesy Richard G. Badger.*)

These insect eaters, or *entomophagous insects,* as they are called, are advantageously considered in two groups known as (*a*) *predators* and (*b*) *parasites. Predators* (Figs. 28 and 29) are insects (or other animals) that catch and devour smaller or more helpless creatures (called the

prey), usually killing them in getting a single meal. The prey is generally either smaller, weaker or less intelligent than the predator. *Parasites* are forms of living organisms that make their homes on or in the bodies of other living organisms (called the *hosts*) from which they get their food (Fig. 30). The hosts are usually larger, stronger or more intelligent than the parasites and are not killed promptly, but continue to live during a longer or shorter period of close association with the parasite. An important difference between these two groups is that, in parasitism, the host makes or determines the *habitat* for the parasite; whereas the prey does not necessarily fix the habitat for the predator, which lives quite independently of its victims during the intervals between meals. Another useful distinction is that, generally, a parasitic larva requires only a single individual of the host species to nourish it to maturity, while a predaceous insect takes many individual victims in completing its development.[1]

FIG. 30.—Insect parasites: larvæ of a parasitic wasp (*Apanteles fulvipes*), leaving the body of the still living, but doomed, host (a caterpillar of the gypsy moth) after having fed within its body for several weeks. (*From U. S. D. A. Bur. Entom. Bull.* 91.)

Phytophagous parasites are those which live upon plant hosts. Insects that parasitize the larger animals (especially domestic animals) may be called *zoophagous parasites*. Insects that parasitize other insects are called *entomophagous parasites*. Zoophagous parasites as a group are highly injurious to man (see p. 767); the entomophagous parasites are largely beneficial to us.

There are numerous kinds and gradations of parasitism. The term *permanent parasite* is used for those parasites (such as the blood-sucking lice) which spend all their time and all life stages on or in the body of the host. *Transitory parasites* are those that pass certain life stages with one host and during other life stages are either free-living, like the horse bot, or parasitic in the body of an alternate host of a different species, such as the protozoan that causes human malaria. The term *intermittent parasitism* is used by some authors for such attacks as those of mosquitoes or bedbugs, which approach the host only at the time of feeding and, after the meal, leave the host for a period of free living. Other authors call such an attack *predatism*. *Obligatory parasites* are those which can live on only one species of host; for example, many of the chewing lice. *Facultative parasites* are those which, like the common flea of cats and dogs, can shift successfully from one species of host to others. Parasites that live on the outside of the body are known as *ectoparasites*, while those that enter the body or eggs of their hosts are known as *endoparasites*.

A classification of parasitism that we shall have to bear in mind is that, with respect to a given host, a parasite or predator may be primary, secondary, tertiary, or quaternary. Not all entomophagous parasites are beneficial to man, and indeed it is sometimes almost impossible to tell whether the presence of a parasitic species in a given territory would

[1] See SMITH, HARRY S., "An Attempt to Redefine the Host Relationships Exhibited by Entomophagous Insects," *Jour. Econ. Entomol.*, October, 1916.

be beneficial to man or injurious. If we have an injurious insect such as the cotton-boll weevil, any parasite attacking it is *primary* for the cotton-boll weevil, and helpful to man. That parasite may in turn be attacked by a parasite, which is then *secondary* to the cotton boll weevil and inimical to man. A parasite attacking such a secondary parasite would be known as a *tertiary* parasite of the cotton boll weevil, and would in this capacity be beneficial to man. All the parasites of a primary parasite are collectively known as *hyperparasites*. When abundant, the hyperparasites may completely offset the beneficial work of primary parasites. How complicated the interrelations of good and bad parasites may be is illustrated by the accompanying diagram (Fig. 31) of the various parasites and predators associated with the cotton boll weevil.

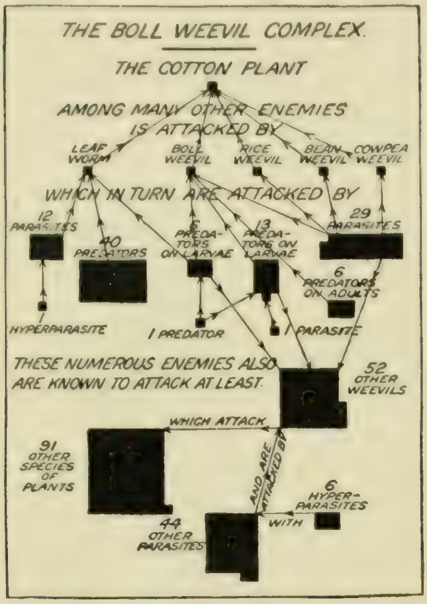

Fig. 31.—Diagram illustrating the interrelations of some helpful and harmful parasites and predators associated with the cotton boll weevil. (*From U. S. D. A. Bur. Entom. Bull.* 100.)

The practical man should make an effort to become acquainted with the typical appearance and manner of life of the more important groups of predators and parasites; and those scientifically inclined can hardly find more fascinating groups for study.

Insect Predators.—Among the best-known entomophagous predators are the following:

Dragonflies, Order Odonata
Aphid lions, Order Neuroptera, Family Chrysopidæ
Ground beetles, Order Coleoptera, Family Carabidæ
Lady beetles,[1] Order Coleoptera, Family Coccinellidæ
Flower flies, Order Diptera, Family Syrphidæ.

Everyone knows the *dragonflies*, though he may have had another name for them; snake-feeders, for example, or snake-doctors, or devils' darning-needles, or horse-stingers (Fig. 103). These unsavory names suggest several bad characteristics, which is wholly unjust; for dragonflies are distinctly helpful to man. All of these names are applied to adults; but if the nymphs (Fig. 103, *1* and *3*), which develop for a year or two in the water before the winged stage appears, were more generally seen they would probably have as many and as romantic names as the adults. Tillyard says "they are the most powerful determining factor in preserving the balance of insect life in ponds, rivers, lakes, and their surroundings."

Much unwarranted fear would be spared if only people could be brought to know that these creatures neither bite, sting, feed snakes, nor perform sorcery. They are

[1] Also called "ladybirds" and "ladybugs."

best known from their habit of sculling, soaring, and darting about near and over ponds and streams in a manner to arouse the envy of the most dare-devil aviator. The swiftest of them attain a speed of nearly 60 miles an hour.[1] They both catch and eat their prey while on the wing. Tillyard found over a hundred mosquitoes in the mouth of a dragonfly at one time. The same author fed mosquito larvæ to a hungry dragonfly nymph which swallowed 60 of them in 10 minutes. It seems likely that these insects are a help in keeping down mosquitoes. The adults also are known to catch flies, beetles, moths, and wasps, many of which are doubtless injurious to man.

Aphid Lions.—These voracious creatures are the young of delicate, gauzy-winged, weak-bodied insects called lace-winged flies or golden-eyed flies (Fig. 32). In the

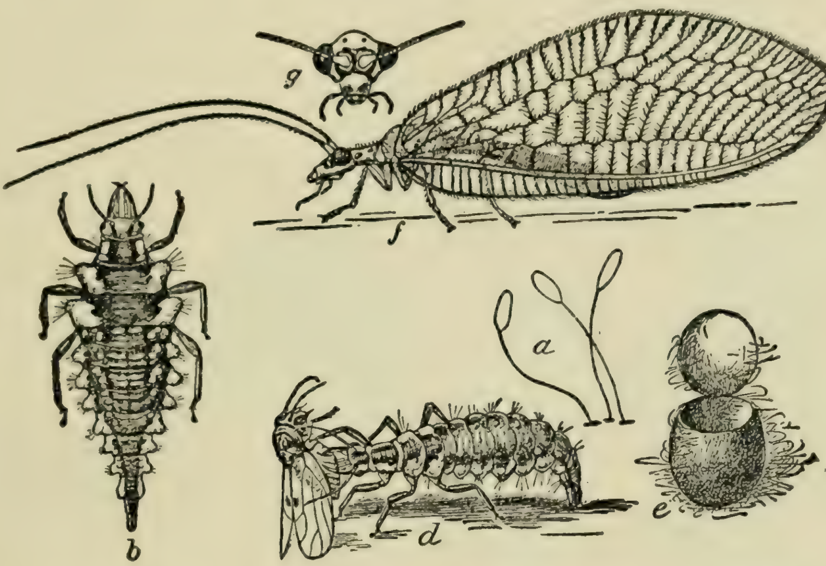

FIG. 32.—An aphid lion or lace-winged fly: *a*, several eggs showing the long pedicels that elevate them; *b*, larva dorsal view; *d*, larva feeding on a plant louse; *e*, empty cocoon showing lid through which the adult has escaped; *f*, adult side view; *g*, head of an adult from in front. (*From Marlatt, U. S. D. A.*)

adult stage (*f*) these insects probably have little importance to man, but their larvæ (*b*, *d*) are very beneficial. Their white eggs (*a*) are curious objects on long slender stems high above the surface to which they are attached (Fig. 73, *R*). Such egg masses are often found on the leaves or stems of trees, vegetables, or field crops. A little later the spindle-shaped larvæ that transform from them may be found scurrying about on the plants in search of aphids. They have very long, sharp-pointed jaws, or mandibles, with which they grasp and puncture the bodies of aphids or other small, soft insects, or their eggs. These mandibles have grooves along their ventral surface against which the maxillæ fit to make two closed tubes through which the juices of the victim are sucked into the mouth. The aphid lions spend the winter in small, white, silken, spherical or oval cocoons (Fig. 32,*e*) about the size of a common elderberry. In the spring the adult cuts off a circular lid through which it makes its escape.

Ground Beetles.—The exact food habits of the *ground beetles* (Fig. 33) are less well known. One finds the general statement "they are beneficial because of their predaceous habits"; or, since "both larvæ and adults feed on many of our most noxious insects, ground beetles must rank among the farmer's best friends." At least a few of the species are injurious by feeding on seeds and berries, and the food habits of most of the 1,200 or more American species have never been recorded. But certain species are

[1] TILLYARD, "The Biology of Dragon Flies," Cambridge University Press, 1917.

known to be very valuable;[1] and, in general, these flattened, black or brown, long-legged, swift-running, strongly-built "caterpillar hunters" are probably helpful to man. They hide during the day under stones, boards, logs, in the grass, or below the surface of the soil, and hunt chiefly at night. The larvæ are slender, a little flattened, slightly tapering to the tail, which terminates in two bristly, hair-like or spine-like processes.

Lady Beetles.—The lady beetles (Fig. 34) will need introduction to very few persons. Their bright bodies, their active habits, their great abundance and equitable distribution, and popular songs and stories, all combine to insure that nearly all of us make their acquaintance at an early age. They are nearly hemispherical in shape. The

FIG. 33.—European ground beetle, *Calosoma sycophanta*, adult, at right, feeding on pupa of gypsy moth and larva, at left, feeding on caterpillar of gypsy moth. (*From Mass. State Forester.*)

commonest species are red, brown, or tan usually with black spots; a few are black, sometimes spotted with red. In size they are commonly from 1/16 to 1/4 inch long and about two-thirds as broad. Some of the destructive leaf beetles look much like lady beetles. The student need never confuse these two groups if he will remember that the lady beetles have three-segmented tarsi, the leaf beetles four segments in each tarsus.

Both the adults and the larvæ of the lady beetles feed on scale insects, aphids, or other small, soft-bodied creatures or their eggs. The larvæ of lady beetles (Fig. 35, *center*) are carrot-shaped and resemble somewhat the aphid lions in their flattened, gradually tapering bodies, distinct body regions, long legs, and warty or spiny backs. They do not have the inordinately long mandibles or extra-wide thoracic segments of the aphid lions, and are generally more conspicuously colored with patches of blue,

[1] A European species (*Calosoma sycophanta* Linn.) has been introduced into New England to prey on the gypsy and brown-tail moths (see *U. S. Dept. Agr. Bur. Entomol., Bull.* 101, 1911).

black, and orange. The pupæ (Fig. 35, *right*) are not enclosed in cocoons, but are exposed on the leaf to which the tips of their abdomens are cemented. When disturbed, they have the curious habit (possibly protective) of lifting the body into a vertical position and soon dropping back again. The orange eggs of many lady beetles are placed in small masses of a dozen or two, the individual eggs standing on end in contact with each other. They should not be destroyed.

In many cases lady beetles have been shipped from one country to another to check insect pests. The most noteworthy case was the introduction of the Australian lady beetle (*Rodolia cardinalis* Muls.) into California to destroy the cottony cushion scale (*Icerya purchasi* Mask.). The cottony cushion scale was unwittingly introduced into California about 1868. It soon became a most serious pest of the orange, spreading rapidly over the state, and by 1890 had killed hundreds of thousands of trees, and threatened to wipe out the orange industry over the entire state. It was traced to

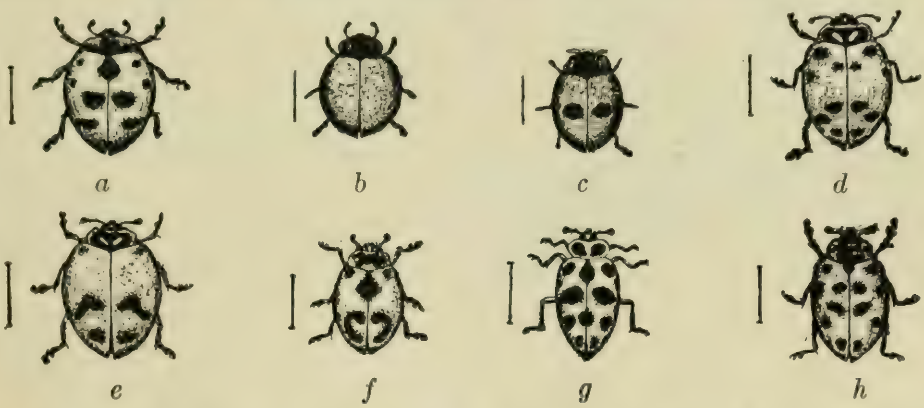

FIG. 34.—Some common lady beetles: *a*, the nine-spotted lady beetle, *Coccinella novemnotata* Hbst.; *b*, the red lady beetle, *Cycloneda munda* Say; *c*, the two-spotted lady beetle, *Adalia bipunctata* Linn.; *d*, the convergent lady beetle, *Hippodamia convergens* Guer.; *e*, the glacial lady beetle, *Hippodamia glacialis* Fab.; *f*, the parenthesis lady beetle, *Hippodamia parenthesis* Say; *g*, the thirteen-spotted lady beetle, *Hippodamia tredecimpunctata* Linn.; *h*, the spotted lady beetle, *Megilla fuscilabris* Muls. The ground color of the spotted lady beetle is pink; of the others yellowish or tan. (*From Conn. Agr. Exp. Sta. Bull.* 181.)

Australia and New Zealand; in New Zealand it was very destructive, also, but in Australia little injury resulted from it. Accordingly the United States government sent an entomologist to Australia to search for the natural enemies that it was felt must be holding it in check there. The lady beetle was found. Some 500 of them were carefully shipped to California. They were turned loose on screened orange trees and allowed to feed on the cottony cushion scale. Within a year and a half the progeny of these few beetles had increased to such numbers that they had checked the cottony cushion scale over the whole state. They have since nearly eliminated this worst of orange insects as a pest in California. The same species of lady beetle has been shipped subsequently to New Zealand, Egypt, Hawaii, Italy, Syria, and Cape Colony, as the cottony cushion scale appeared in these countries; and it has never failed to bring the scale under subjection.

Syrphid Flies.—Another important group of predators that rival in importance the lady beetles and the aphid lions are the creatures known as syrphid flies, flower flies, or sweat flies (Fig. 36). Agreeing with the aphid lions but unlike the lady beetles, they are predaceous only in the larval stage; the adult flies never attack other insects. It is a rare aphid colony, however, that does not have from one to many of the elongate, footless, slug-like, tan, or greenish maggots of these flies (Fig. 36, *C*) preying upon it. Hidden among the aphids or quietly looping about over the surface of the plant, these

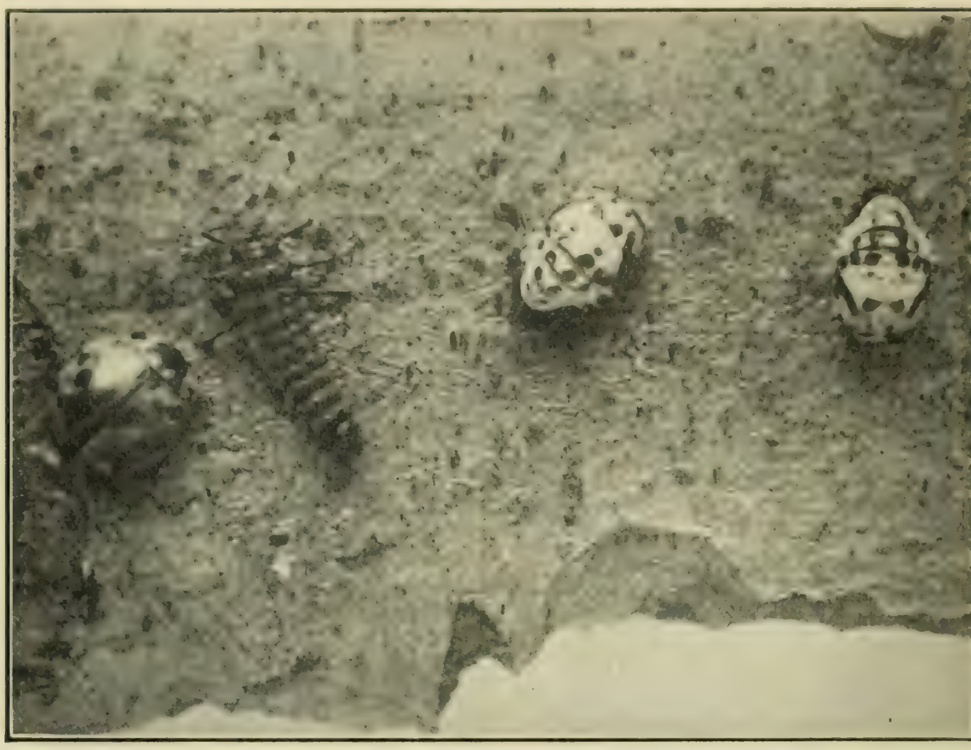

FIG. 35.—The fifteen-spotted lady beetle; adult at left, larva next, two pupæ on the right. (*From Conn. Agr. Exp. Sta., Bull*, 181.)

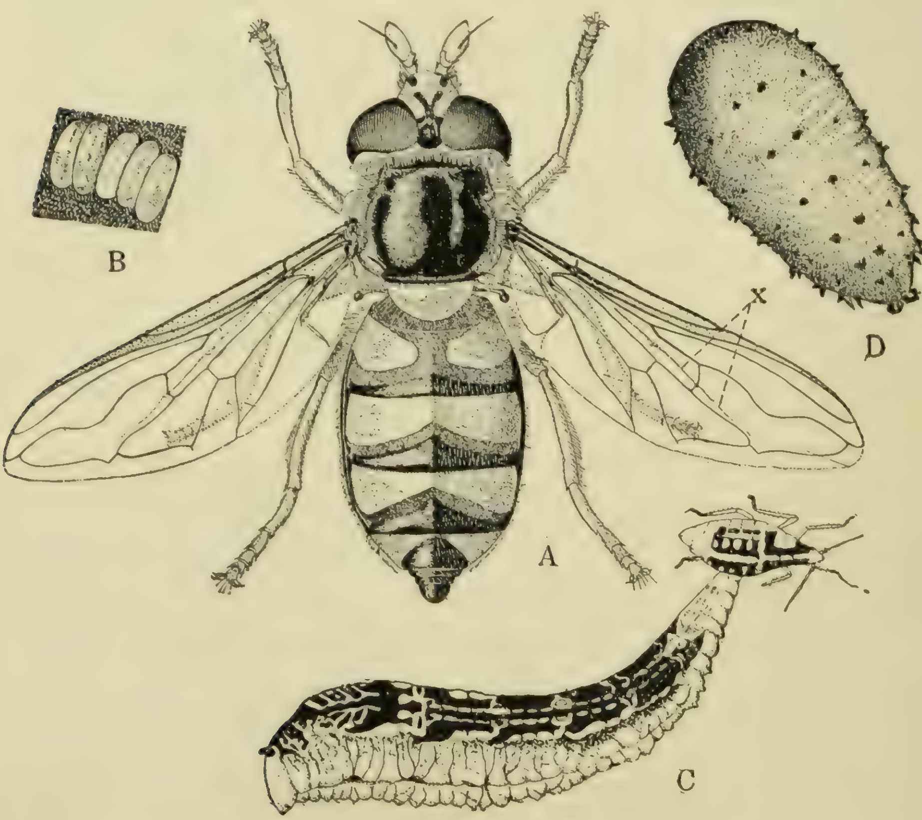

FIG. 36.—A syrphid fly: *A*, adult of *Didea fasciata* Macq.; *x*, the false vein in the wing that characterizes flies of this family (*after Metcalf, from the Ohio Naturalist*); *B*, eggs of *Melanostoma mellinum* Linné (*after Metcalf from Me. Agr. Exp. Sta. Bull.* 253); *C*, larva feeding on an aphid (*redrawn after Jones, Colo. Agr. Exp. Sta.*); *D*, puparium of *Didea fasciata* Macq. (*after Metcalf, from the Ohio Naturalist*).

larvæ grasp aphid after aphid by their pointed jaws, raise it in the air, and slowly pick out and suck out all the body contents, finally discarding the empty skin. A syrphid-fly larva often destroys aphids at the rate of one a minute over considerable periods of time. It is difficult to measure the great service thus performed. The adults lay their glistening-white, elongate eggs (Fig. 36, *B*) usually one in a place, among groups of aphids. They themselves feed on nectar and pollen and have considerable value as pollinizers. Adult syrphid flies are often confused with wasps and bees. They are generally banded or spotted with bright yellow or covered with long black and yellow hairs that give them a very striking general resemblance to stinging insects. They can be distinguished by having only one pair of wings, by their hovering or poising flight, and by the presence of the false vein (x, Fig. 36, A) in their wings.

The number of predators working in a field is often astonishingly large. W. G. Johnson records that in packing peas in southern Maryland in 1899, the separators sieved out in a few days about 25 bushels of larvæ of Syrphidæ, chiefly one species. They were so abundant that they almost completely destroyed the pea aphids in the fields. J. E. Dudley reports that in using a new type of aphidozer or trap to collect pea aphids from pea fields in Wisconsin, he collected with the aphids from 2½ acres, 1,523 syrphid-fly larvæ, 173 adults and larvæ of lady beetles, and 42 other predators.

Insect Parasites.—The most valuable *entomophagous parasites* are probably contained in the following families:

Tachinid flies, Order Diptera, Family Tachinidæ
Ichneumon wasps, Order Hymenoptera, Family Ichneumonidæ
Braconid wasps, Order Hymenoptera, Family Braconidæ
Chalcid wasps, Order Hymenoptera, Family Chalcididæ
Egg parasites, Order Hymenoptera, Family Scelionidæ

These families of entomophagous insects differ from the predators just discussed in that they enter the body of the victim and feed for a period of time on blood or tissues, instinctively avoiding vital parts, usually until the parasite is full grown. By that time or shortly afterward the victim dies and the parasite completes its transformation to an adult either within or without the dead body of the host. Representatives of all insect orders and all life stages from egg to adult may be thus attacked by the various parasites.

Tachinid Flies.—One of the most important families of entomophagous parasites is the group of flies known as Tachinidæ. Many of the species resemble superficially a much overgrown house fly, being very bristly, usually grayish, brownish, or black-mottled flies, without bright colors (Fig. 37). They may be distinguished at once from the house fly family, however, by the entirely bare bristle on the antenna. The adults are found chiefly resting on foliage or about flowers upon which they feed, but may often be seen attacking the caterpillars of moths and butterflies which are the commonest hosts of their larvæ.

The eggs of the tachinid flies are glued to the skin of the host or laid on foliage where the host insect may ingest them; or already hatched larvæ are deposited on the body of the victim or beneath its skin. They feed at the expense of muscular and fatty tissues not absolutely necessary to life, and the host caterpillar may complete its growth and form a chrysalid or cocoon before it dies. From the cocoon, however, emerges the parasitic fly instead of the moth or butterfly. Whenever army worms become abundant, one of the noticeable features of the outbreak is the great numbers of

flies that are buzzing about. Farmers often think that these flies "make" the army worms. But the parents of the army worms are tan-colored moths (Fig. 205); and these flies[1] are one of their principal natural enemies. If you examine the back of an army worm, you will generally find the small white eggs of this fly glued to the skin, in numbers ranging from 1 to 50 (Fig. 204, upper worm). Few of the eggs are found farther back on the body than the thorax—seemingly a nice protective instinct on the part of the parent fly, since the worm could bite off the eggs deposited toward the rear end of its body. Upon hatching, they tunnel directly through the skin and within a short time their maggots may have killed the caterpillars by thousands.

Fig. 37.—A tachinid fly, *Winthemia quadripustulata* (Fab.); a fly that lays eggs on army worms and whose larvæ destroy the worms. About five times natural size. (*From U. S. D. A. Farmers' Bull.* 752.)

The remaining parasites listed above are all Hymenoptera. Although they are commonly spoken of as "flies," the authors prefer the terms ichneumon wasps, braconid wasps and chalcid wasps, as these insects are really small wasps. They are, therefore, four-winged insects; the females are provided with a sharp ovipositor (homologue of the "stinger" of bees), with which the eggs are generally thrust into the flesh of the host beneath the skin. These families of parasitic Hymenoptera are both extremely large in numbers of species and extremely difficult to classify. For the practical man, it is probably sufficient to know that most of these parasites can be recognized by having a divided or two-segmented trochanter (Fig. 47, *D*) and a slender petiole or fore part of the abdomen next to the thorax.

Egg Parasites.—The family Scelionidæ includes some of the smallest of known insects, many of them egg parasites and of such a size that they derive all their nourishment and grow to maturity inside of a single egg of another insect. They are mostly slender, non-metallic, minute wasps with usually straight antennæ, few wing veins, and the ovipositor attached at the tip of the abdomen.

[1] *Winthemia quadripustulata* (Fab.), Order Diptera, Family Tachinidæ.

The chinch-bug-egg parasite[1] (Fig. 38) greatly cut down the hatch of chinch bugs in Kansas during 1913. The extent of parasitism for the state of Kansas was calculated at about 16 per cent; that is 16 out of 100 chinch bugs were killed by this enemy. The next season was generally favorable for chinch bugs, but largely because of the good work of this parasite, only 1 bug was found in winter quarters in 1913–1914, where from 25 to 100 had been found the winter before. The life cycle of

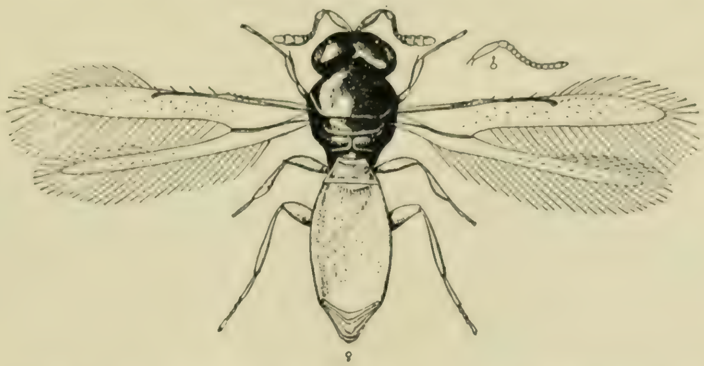

FIG. 38.—The chinch bug egg parasite; adult female greatly enlarged; antenna of male above. (*From Proc. U. S. Natl. Mus., Vol.* 46.)

this parasite occupies only 2 or 3 weeks, so that four or five generations may operate on a single generation of the chinch bug. In 1914, Flint brought from Kansas to Illinois over 100,000 chinch-bug eggs, many of which were parasitized, and colonized the parasites in about thirty localities in the latter state. By concentrating the parasites, the percentage of infestation of the chinch-bug eggs was raised on one farm from less than 10 per cent in 1914 to 53 per cent in 1915. Other species of Scelionidæ live in the eggs of many moths, true bugs, grasshoppers, spiders, and flies, such as the Hessian fly.

FIG. 39.—A chalcid wasp parasite, *Aphycus eruptor*. (*From Comstock's "Introduction to Entomology," Comstock Publishing Co.*)

Chalcid Wasps.—The chalcid wasps are mostly parasitic, though some of the species feed on plants, for example, the jointworm and the fig wasp. Many species live within the minute bodies or the eggs of scale insects, aphids, caterpillars, and flies (Fig. 39). A very beneficial species is *Pteromalus puparum*, which attacks our common imported cabbage worm. Although only $\frac{1}{16}$ inch long, it occurs in such numbers in many sections as greatly to reduce the numbers of the cabbage worm. More than 3,000 individuals have been reared from a single specimen of the cabbage worm. Not all the parasitic chalcids are beneficial to us, because there are many hyperparasites or secondary parasites.

[1] *Eumicrosoma benefica* Gahan. See *Jour. Econ. Entomol*, Vol. 8. p. 248, April, 1913.

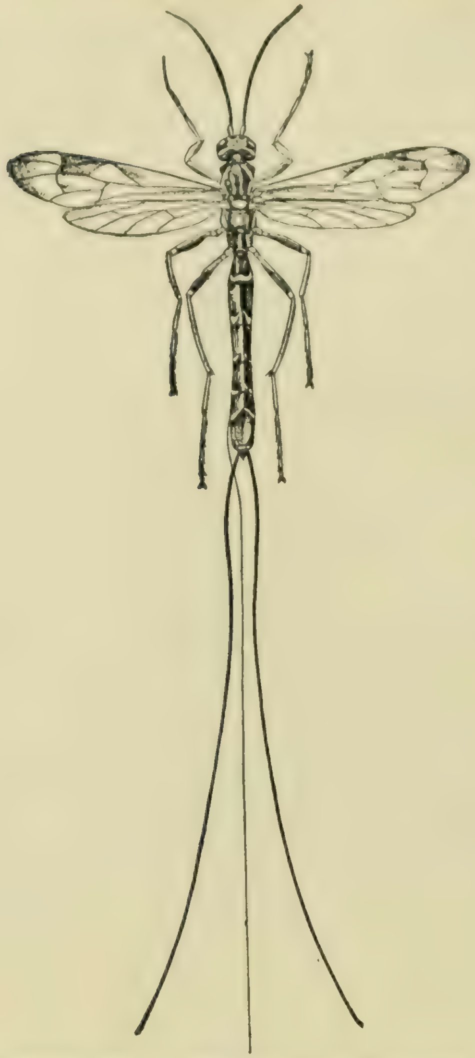

FIG. 40.—The long-sting, *Megarhyssa lunator* (Fab.), an ichneumonid parasite of the pigeon tremex. (*From Kellogg's "American Insects."*)

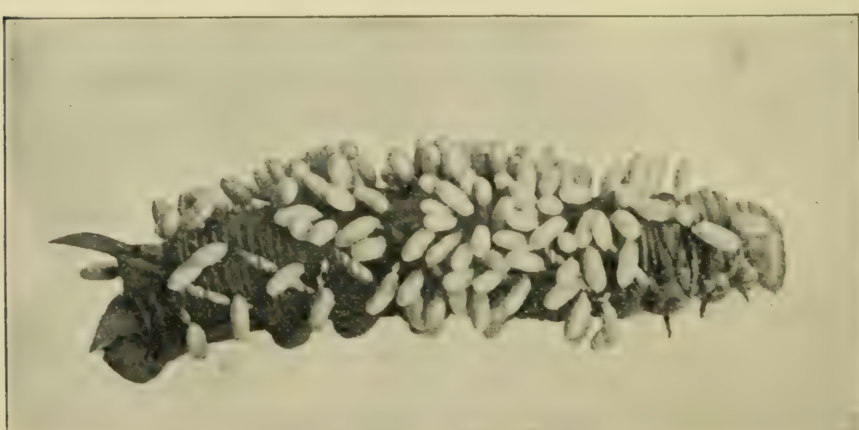

FIG. 41.—A sphinx caterpillar covered with the cocoons of a braconid parasite. The larvæ of the parasite develop inside the body of the caterpillar, which eventually dies as a result of the attack. (*From Sanderson and Jackson, "Elementary Entomology."*)

These wasps are generally of a metallic luster, with elbowed antennæ, and with the ovipositor hidden but attached to the ventral surface of the abdomen some distance before the tip. The wings generally show a single vein parallel with the costa and slightly forked at its tip (Fig. 39).

Ichneumon Wasps.—This family includes the largest of our parasitic species, as well as some very minute ones. They are often brilliantly marked. When active they "can generally be recognized by their short, jerky flight and constantly vibrating antennæ" (Lefroy). The very large long-sting or *Megarhyssa* (Fig. 40), 1½ inches long, with tail-like ovipositor nearly 3 inches long, may often be found fastened by its ovipositor in the side of a tree trunk. They thrust this marvelously thin and

FIG. 42.—Aphids parasitized by a braconid wasp, *Lysiphlebus testaceipes* (Cresson). Adult wasps have emerged through the circular holes after having killed the corn leaf aphids by developing in their bodies. Nearly 100 per cent of the aphids were parasitized. (*From Essig, "Insects of Western North America," copyright,* 1926, *by the Macmillan Company; reprinted by permission.*)

strong ovipositor into the wood until it strikes the burrow of a wood-boring larva (the pigeon tremex, see Fig. 145) when an egg is inserted. The parasitic larva upon hatching from the egg crawls along the tunnel until it encounters the wood-boring larva which it then attacks. Possibly the adult long-sting locates the position of the wood-boring larva by the sounds it makes in tunneling through the wood. Most ichneumons attack caterpillars, with resultant great benefit to man.

Braconid Wasps.—Commonly one sees specimens of tomato hornworm or catalpa sphinx whose backs are covered with small, elongate, white objects glued by one end to the skin of the caterpillar (Fig. 41). They are commonly called "eggs" and seldom understood. In reality they are silken cocoons enclosing the pupa stage of a species of braconid wasp of the genus *Microgaster.* The parent wasp had previously thrust many eggs through the skin of the larva; her larvæ had fed within the tissues of the caterpillar and when full grown they had eaten out through the body wall again,

to spin their cocoons fast to the host. Some other species leave the host and form their cocoons in masses on a leaf near-by their dead victim.

If one examines carefully almost any leaf that is infested with aphids, one will see some specimens of the aphids whose bodies are distended, shiny, and brown and many of them with neat circular holes cut in their backs (Fig. 42). This illustrates the work of some of the smallest of the braconid wasps; for example, the genus *Aphidius*. Still other of the braconid wasps attack dipterous larvæ, ants, cockroaches, beetles, bees, and wasps, and some even swim with their wings beneath the water to parasitize such aquatic insects as caddice worms.

Insects and Weeds

Whether an insect is injurious or beneficial depends more often than anything else upon the economic status of the thing or material it eats. That great horde of insects that feeds on weeds or attacks noxious animals must perform a very valuable service. Anyone who stoops to notice the abundance and variety of insects on almost any bit of wild vegetation will need no arguments to convince him that these plants suffer grievously from insect attack. To a corresponding degree they help the farmer, who has to contend with these undesirable plants.

The milkweeds of the middle west are attacked by great numbers of the red milkweed beetle (*Tetraopes tetraophthalmus* Forst.), the blue milkweed beetle (*Chrysochus auratus* Fab.), the monarch or milkweed butterfly (*Danaus archippus* Fab.), and many other species. In the same territory the rough pigweed has for several seasons been covered with thousands of specimens of a small lace bug (*Piesma cinerea* Say). A species of hornworm (*Celerio lineata* Fab.), has been recorded as destroying such weeds as purslane and fireweed over great areas. Glick (unpublished manuscript) records a species of plume moth (*Platyptilia carduidactyla* Riley) to have destroyed 90 per cent of the flower heads of pasture thistle in some localities. The same author records a species of sawfly as having eliminated purslane from a 10-acre field of onions, although neighboring fields were much troubled with this weed.

This beneficent work is unfortunately not without its drawbacks. Too often insects that have increased at the expense of weeds subsequently shift their attack to cultivated crops. This is especially likely to occur when the weeds are botanically close relatives of the cultivated crop. For example, the writers have often seen numbers of flea beetles and tomato hornworms developing in hog lots, barnyards, fence rows, and fields, where jimson weed, horse nettle, and morning glories were allowed to grow in profusion. A little later these pests shifted to adjoining potato, tomato, or tobacco plants. Forbes has shown that the corn root aphid is dependent in the early spring upon such weeds as smartweed, foxtail, ragweed, purslane, and crab grass, before corn is planted. The common stalk borer (*Papaipema nebris nitela* Guen.) is seldom destructive to corn or other cultivated crops except along the margins of fields where the larvæ have begun development on grasses or weeds. The bean aphid (*Aphis rumicus* Linn.) is often very abundant on pigweed and dock, from which it easily migrates to beans, dahlias,

euonymus, etc. The spinach flea beetle increases in the early part of the season at the expense of such weeds as chickweed and *Chenopodium*. The tarnished plant bug occurs in such numbers on ragweed, pigweed, common mallow, goldenrod, evening primrose, and wild asters as to constitute a considerable check to their development. But while they are checking these weeds they are also increasing their own numbers for a probable later invasion of our nurseries, orchards, and flower gardens. The thistle butterfly or painted lady, in periods of abundance is sometimes hailed as a destroyer of Canada thistle. But it is also likely to feed injuriously upon some cultivated crops. Even insects that are not at present known to attack any cultivated crop may change their food habits, desert their weed hosts, and adapt themselves almost exclusively to a new and valuable food plant. Such a shift is known to have occurred in the case of the Colorado potato beetle.

We may fairly sum up this phase of the subject with the statement that, while we are not unmindful of the vast service performed by insects in checking weed growth, we cannot encourage their development or even look with favor upon the great natural increase of any species, especially in proximity to cultivated crops, because of their potential injury to valuable plantings.

A gigantic experiment has been under way for several years in Australia in an effort to destroy the cactus, which is such a pest in that country that it forms impenetrable forests over thousands of square miles. A number of cactus-feeding insects have been introduced from Mexico and other lands and are giving real promise of destroying the cactus and solving this otherwise baffling problem. Elaborate tests have been made in every case to insure that the insects so introduced will feed on nothing but cactus. The result of this experiment will be watched with great interest.

Insects as Soil Builders

To be productive of plant growth, a soil must contain at least the following substances: minute mineral particles derived from disintegrating rocks, organic substances derived from dead plants and animals, water, and air.

In the production or maintenance of all of these things, insects play an important part. They help to break up the rock particles, and, by bringing them to the surface, expose them to the action of water and other weathering influences.

"Briefly, these benefits . . . may be classed as an interchange of soil, separation of soil, aeration, drainage, and addition of organic matter . . . Shaler found ants so numerous in a field near Cambridge, Mass., that they transferred enough material each year to cover the surface of the ground with one-fifth of an inch of new soil."[1]

The numerous tunnels made by the insects facilitate the circulation of air into the soil, so essential to the health of plants. Insects burrow to depths ranging

[1] McCulloch and Hayes, "The Reciprocal Relation of Soil and Insects," in *Ecology*, Vol. 3, No. 4, pp. 288–301, October, 1922.

up to at least 5 feet for white grubs and 10 feet for the nymphs of cicadas. These burrows doubtless have considerable importance in the movements of capillary water. Finally, insects are of inestimable value in adding humus or organic matter to the soil. This is accomplished in several ways. The dead bodies of the insects themselves accumulating on the surface are a fertilizing element. Especially is this noteworthy in the case of insects like May-flies, which develop in countless numbers in the water of our lakes and streams and then, as adults, fly inland and often perish to form great windrows of dead insects about lights. The excreta of insects is a rich manure, comparing favorably in chemical content with that of the larger animals and in total amount undoubtedly exceeding the latter.

In burrowing through the ground, insects bring up the subsoil particles, and cover plant and animal materials lying on the surface. Others carry plant and animal particles into the soil in connection with their feeding or nesting activities: as termites, ants, cutworms, burying beetles, dung beetles, and predaceous wasps. This is somewhat similar to plowing under a cover crop.

Here, as in most of the other relations of insects, their small size is abundantly offset by their unparalleled numbers. Wheeler says that ants outnumber in individuals all other terrestrial animals. The earthworm as a soil builder has been brought prominently to our attention by the writings of Darwin; it seems to the writers that insects as a whole must equal or excel earthworms in the formation, fertilization, and renovation of soils.

A great variety of insects is found in the soil, representatives of practically all of the natural orders. The most abundant are ants, bees, wasps, beetles, the larvæ of flies, cutworms, the pupæ of moths, cicadas, crickets, and springtails. These creatures have been found in the soil in abundance beyond our comprehension. Different counts indicate a frequency of 1,000,000 per acre, 3,500,000 per acre and over 10,000,000 individuals per acre. Margaret Windsor (unpublished thesis) found insects occurring in the forest soil in Illinois, to the depth of 18 inches, at an average frequency of 65,000,000 to the acre.

Insects as Scavengers

One of the most interesting ecological groups of insects is that group that feeds on the decaying substances of plants and animals. Their service is twofold: in the first place, they help to remove from the earth's surface the dead and decomposing bodies of plants and animals, converting them into simpler and less obnoxious compounds, and removing what would otherwise be a menace to health; and in the second place, they play a very important part in converting dead plants and animals into simpler substances which can be used as food for growing plants. Repulsive as they may be, we can not scorn the beneficent work they do. In this work the larvæ of many flies and the larvæ and adults of beetles are especially important. A fascinating story of the lives of some of the beetles is told by Fabre in "The Life and Love of the Insect."

The Scientific and Æsthetic Value of Insects

The final service of insects that we will mention is, in a way, the least tangible of all, and perhaps most readers will think it the least important. Insects rival birds and flowers in beauty; and there are many more of them. Moths and butterflies are universally admired. But there are thousands of kinds of beetles, bees, flies, leafhoppers, planthoppers, dragonflies, mantids and others that will be found every

bit as handsome as moths and butterflies by anyone who will examine them through a microscope or magnifying glass.

Much practical use has been made of the beauty of insects. Artists, florists, milliners, and designers have drawn extensively from the Lepidoptera, and might profitably draw much more extensively upon the inexhaustible grace of line, and beauty of color, so lavishly displayed in the less well-known kinds of insects. Insects are widely used as ornaments. In larger cities one finds stores dealing in trays, pins, necklaces, etc., of which the sole claim to beauty is the actual bodies of preserved insects. The reader should not gain the idea that many insects have a very great commercial value. One of the drawbacks of being an entomologist is the frequent necessity of disillusioning some trusting youngster who has reared his first Cecropia moth and has hastened to the nearest "bugman" to sell his valuable (?) find.

In the Bahamas, South Africa, and Australia, the natives often wear strings of what are called "ground pearls," which have been found to be the case or shell secreted by the nymphs of a kind of scale insect. They are irregular in shape, of a variety of colors, and often have a beautiful luster or irridescence. In the Caribbean Islands, living fireflies are enclosed in gauze and worn as hair ornaments.

The songs as well as the form and colors of insects have been of much interest from earliest times. The natives of South America, Africa, Italy, and Portugal cage katydids and crickets for the sake of their songs; and highly ornamented cages containing these little songsters are sold in the streets.[1] One of our entomologists[2] has taken much pains to assemble the poetry based on insects, in the English language alone, from 1400 to 1900 A. D. He records having found over 1,200 separate excerpts, including about 75 complete poems.

The curious habits, structures, sounds, and interactions of insects continually afford profitable diversion or hobbies to a small army of amateur entomologists, ranging from care-free children to staid scientists and millionaires. The Chinese have elaborate cricket fights, contested by champions that are as carefully fed and trained as American race horses and that sell for $5, $10, or even $50 each.

The great abundance and variety of insects have resulted in their selection for many scientific studies and fundamental biological investigations. In recent years, the geneticists, appreciating the blood relationship of all animals, have realized that many of the foundation principles of inheritance, variation, and race improvement could be revealed as clearly by insects as by the more expensive, more cumbersome, slow-breeding rat, guinea pig, mouse, or rabbit. The ease of handling, the rapidity of multiplication (a generation being completed in about 10 days), and the cheapness with which they can be kept and reared have made the minute pomace fly, or *Drosophila*, the favorite subject for students of genetics.

[1] CAUDELL, A. N., "An Economic Consideration of Orthoptera Directly Affecting Man, *Smith. Inst. Ann. Rept.*, 1917, pp. 507–514.

[2] WALTON, *Proc. Entomol. Soc., Washington*, October and November, 1922.

Summary

We see, therefore, that many comforts and luxuries, much food, certain dyes and medicines, and our choicest clothing come from insects; that insects are useful in scientific investigations, in improving the soil, in pollinizing fruits, flowers, and vegetables, in checking weed growth, as scavengers, and as food for birds and fishes and even for men; and that our very tenure on the earth is probably dependent upon the friendly ones (parasites and predators) among our most numerous animal relatives, the insects.

CHAPTER III

THE EXTERNAL MORPHOLOGY OF INSECTS

Insects are among the humblest and lowliest of animal creatures; man belongs to a species that has been called the dominant species. Yet it has been shown in the preceding chapters that insects dispute with man for the possession of most of the things he values and often succeed in getting the greater part of the product of his labors. The present chapter is an attempt to analyze the success of insects as a group of animals living in keen competition with thousands of others.

Why have the insects, rather than worms, birds, or rodents become the most numerous of all animal groups? What is there about insects that has made it possible for them to increase continually in number and variety, while some other animal groups have become extinct or merely held their own? There must be sound reasons for this: the competition in the fields, forests, and waters of the earth is so intense that no species can long *survive*, much less *increase* in numbers, unless it be well fitted for living in its particular environment.

Every species overproduces. A single pair of house flies, and their descendants, increasing without restriction, would in one season produce enough flies to suffocate man and all other animals on earth. Some kinds of insects succeed in increasing to the point where they constitute plagues, but no species has yet achieved anything like the rate of increase of which it is theoretically capable. The reason is that the competition for food, water, places wherein to lay eggs, indeed even for standing room, becomes a bitter struggle as soon as numbers approach the point of crowding. This struggle is so intense among the wild animals, including insects, that the great majority of all creatures born into the world die before reaching maturity. Anyone can verify this by following the history of a nestful of birds, a nest of tent caterpillars, or a colony of tadpoles in a pond.

There is good evidence for believing that death due to the struggle for existence is not indiscriminate; that some have a better chance of surviving than others; that generally, and in the long run, those creatures that are best fitted for life will be the ones that survive. The fly that is slowest to take wing (whether because of poorer vision, or weaker wings, or a more sluggish nervous system) is the one that is caught, whether it be by a swatter in the hand of man, or by the more deadly tongue of a toad. When flies are few and food is scarce, it will be the

toad with the sharpest eyes, the least alarming appearance, the surest aim, the stickiest tongue, and the dragonfly with the swiftest flight, the keenest sight, and the surest grasp that will catch the most flies; while their less efficient brothers and cousins will go hungry, often to the point of starvation. The hopper with the slowest jump may be trampled by the grazing cattle in the field, while his quicker and stronger associates will longest escape this and other calamities. This usually results in the *survival of the fittest,* or at any rate the elimination of the unfit.

By reason, then, of the facts, first, that every year more of every kind are produced than can possibly survive (*overproduction*), and, second, that competition for every necessity is so keen (*the struggle for existence*), we may be sure that a continual and pitiless *natural selection* is going on. It follows that any group that has attained the numerical superiority of the insects, both in species and in individuals, must be unusually well fitted for life. We shall be in a better position to fight those insects that are pests, when we understand their structure and the most important characteristics that fit them for life.

Characteristics That Enable Insects to Compete with Man

The Size of Insects.—One of the greatest factors in the success of insects is undoubtedly their small size. While the largest insects reach a length of 6 to 10 inches, these are very exceptional. The smallest known kinds are less than $\frac{1}{100}$ of an inch long. The average weight of insects is probably not over $\frac{1}{5000}$ ounce to the individual. At first thought, this might appear to be a disadvantage. However, it enables insects to live in cracks and crannies of the plant and animal communities, where competition with the larger animals is not so great. Many insects can subsist on the portions left from the feeding of larger animals. They can retreat into protected places where larger animals cannot follow. They often excape death because they are completely overlooked: very often the first intimation a grower has of the presence of the San José scale in his orchard is the red spotting of the fruit at harvest time.

A small body makes possible feats of strength that, in comparison to size, seem marvelous. Many insects can carry from ten to twenty times their own weight. "A house fly can carry a match, to equal which a man would need to drag a timber 35 feet long and as large around as his body."[1] A flea whose legs are about $\frac{1}{20}$ inch long can jump as far as 13 inches horizontally and $7\frac{3}{4}$ inches high. If length of legs were the only factor involved, we should expect an athlete with legs 3 feet long to make a broad jump of 700 feet, and a high jump of at least 450 feet. The smaller the muscle (other factors being equal), the greater the proportionate work it can do.

[1] Sanderson and Jackson, "Elementary Entomology," Ginn and Company, 1912.

Rapidity of Reproduction.—A second factor in the success of insects as a class is their great reproductive capacity. This is discussed later in the account of the life cycle (p. 138).

The Adaptability of Insects.—In the adaptability of insects we see another superior quality. New structures and new habits are continuously developing. New forms are evolving and old forms changing in accommodation to the constantly changing face of the continent. Within the memory of those still living, certain insects have adapted themselves to new host plants, thus changing from insignificant bugs to major pests. Insects have not restricted themselves to one medium, like the fish or the birds, or to one kind of host, like the parasitic worms; they occur on and in the water, in the air and soil, on animals and plants, and within the bodies of both; in houses, ships, and mills, and in almost all sorts of organic and inorganic substances. The problems in insect control are more serious in areas where the biological and physical environment is undergoing rapid changes, than they are in areas where conditions have become more stable by a long and gradual development. It is one of the greatest tributes to the remarkable variety and plasticity of the insect class that, in the face of rapid and radical changes, *some* species of insect is certain to adapt itself with surprising promptness to the new opportunity, and so successfully that it very soon becomes a serious pest.

The Persistence of Insects.—In the instinctive behavior of insects we see an explanation of their apparent fixity of purpose. They lack both reason and judgment. This would seem to put them at a great disadvantage compared to man; and so it would, individual to individual. But considered in the mass it means on the part of the insect, unfaltering pursuit of the work for which it is adapted. The every-day behavior of the flies about an animal, or in a room when one is trying to sleep, illustrates this point. They cannot be frightened away, or discouraged by repeated assault; they recognize no defeat. So long as life persists within them they continue unflinchingly to procure a living for themselves and to prepare for the next generation.

The Exoskeleton of Insects.—A characteristic of insects that we may be sure has been important in their evolution is the nature of the body wall. Insects have no bones, but are covered all over the outside with a kind of hard shell. This shell is not heavy. It is much lighter and also stronger than bone. It is also remarkably resistant to solution or corrosion, not being affected by any of the ordinary chemicals. Strong acids or alkalies, alcohol, solvents, and the like have no noticeable effect on the outer body wall of insects. Even boiling potassium hydroxide, which quickly dissolves flesh and horn, does not destroy the skin of the insect, unless the treatment is continued for a long time. Because of the unusually stable character of the body wall, insects can be kept, like mummies, for hundreds of years without any preservative;

retaining practically a life-like appearance after death. The practical importance of this we recognize when we attempt to control insects by contact sprays. The great difficulty has always been to find a substance that would attack the body of an insect and kill it without at the same time killing or injuring the plant on which it was feeding.

It is interesting to know how an insect grows the hard shell which covers every part of its body, even the eyes, feelers and mouth parts. A very thin layer of it also extends down the throat, over the posterior part of the alimentary canal, and as an inner lining throughout the length of the breathing tubes. It is formed first as a secretion which is semifluid and covers the entire body like a soft leather glove. The secretion which is known as the *cuticula* comes from a layer of cells just beneath it called the *hypodermis* (Fig. 43). The hypodermis is composed

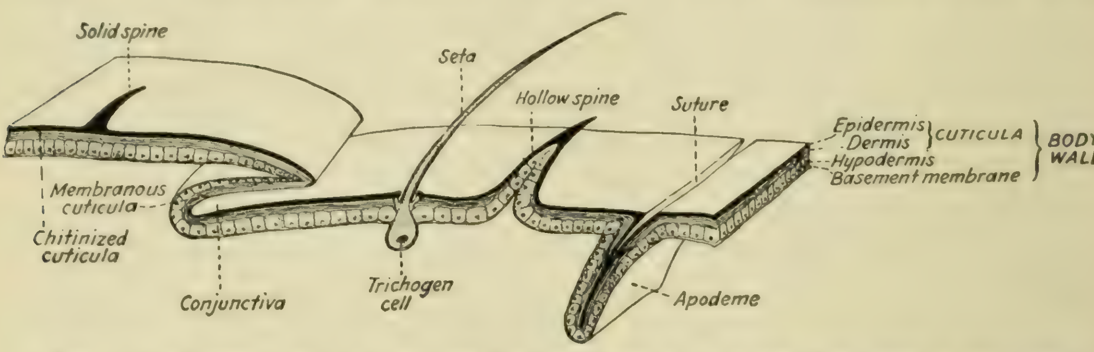

FIG. 43.—A section of the body wall of an insect showing spines, setæ, membranous and chitinized cuticula, an apodeme, a conjunctiva and the several layers of the body wall. (*Redrawn after Comstock and Snodgrass.*)

of a single continuous layer of living cells, while the cuticula is lifeless material like our nails or hair. Both cover the outside of the body completely. As soon as the semifluid cuticula is formed over the body, it begins to harden or "set" much like cement, and in the course of an hour or so it has become as firm and stiff as a sheet of metal armor. This change from flexible to stiff cuticula is due to a chemical process, and the hard material formed is called chitin (pronounced ky′-tin). It contains carbon, hydrogen, nitrogen, and oxygen, and the formula has been given as $C_{30}H_{50}N_4O_{10}$.

On account of this covering of the body, and the absence of bones within, insects are said to have a *chitinous exoskeleton* instead of a bony endoskeleton (Fig. 44). The exoskeleton serves two very important functions. It protects the delicate muscles, nerves, and other organs from excessive evaporation and mechanical injury. It also serves as a framework for the attachment of muscles. In the latter capacity an exoskeleton seems to offer certain advantages over an endoskeleton. It gives vastly greater area for the attachment of muscles and certain opportunities for very effective leverage. As a protective armor it could hardly be improved upon. The typical insect is built with its

FIG. 44.—Skeleton of a mammal and an insect compared: *A*, an animal (cat) with a bony endoskeleton; *B*, an animal (honeybee) with a chitinous exoskeleton. For emphasis certain ingrowths of the cuticula (the endoskeleton of the bee) have been omitted. (*A*, *modified from Davison's "Mammalian Anatomy" P. Blakiston's Son & Co.; B, redrawn after Snodgrass.*)

shell somewhat in the form of a hollow cylinder, which is the strongest type of construction possible with a given amount of material. The ends of the cylinder are closed with more or less convex caps so that from almost any point of attack the insect body presents an arched construction. This protects insects from injury by ordinary blows or in falling; a point of great significance when we consider the very active, apparently reckless, sort of lives most of them lead.

The Segmentation of the Body.—Many animals that are covered with a hard outer shell are sluggish, inactive, and sedentary in habits, like the clams, snails, and barnacles. This is not true of most insects. The latter have achieved the happy combination of an armor plate without sacrificing freedom of movement. This is made possible by the characteristic known as segmentation. As you examine the body of an insect (especially caterpillars), you see that the external wall does not present a smooth, unbroken surface (see Figs. 54, 1 and 46). On the contrary, it is divided by constrictions into a series of ringlike pieces, all connected, yet moving rather freely on each other. The word insect is from the Latin *insectum*—"cut into"—and refers to the manner in which the parts of the body are separated by constrictions. If you examine these joints carefully, you may be able to see that they consist more or less of an infolding or pleating of the body wall (Figs. 44, *B* and 43). At the joints of the body and legs, the cuticula does not become stiff, by the formation of chitin, as it does between the constrictions, but remains soft and elastic.

Segmentation of the body is an important advantage. If we contrast it with the condition shown in other shelled animals, like snails and clams, we see that it permits great freedom of movement and activity. And, in the second place, it facilitates specialization which makes for efficiency. The body so divided into segments may devote one part to securing food, another to locomotion, another to reproduction, another to defense, and so on. It permits *division of labor*, which has always made for success and progress the world over, whether it be in a force of factory workers, in a football team, or in the body of a bumblebee.

The segments of the body are called *somites* or body segments, to distinguish them from the segments of legs, antennæ, and other appendages. (The term "joint" properly refers to the constriction between two segments, and should not be used for the segment.) The flexible portion of the cuticula connecting any two segments is called a *conjunctiva* (Fig. 43). Besides the conjunctivæ, or infoldings between segments, there are many other lines or strips of the body wall that do not become stiff and hard. Such linear infoldings or impressed lines are referred to as *sutures* (Fig. 43) and may run in any direction over the surface of the body. The areas of the body wall bounded by sutures are called *sclerites*. A suture is to a sclerite what a seam is to a patch.

Each body segment is made up of (at most) four exposed faces. The dorsal or upper face is called the *tergum*, the ventral face (the part next to the ground when the insect is in its normal position) is called the *sternum*, and each lateral face or side piece is called a *pleura*. Each of these faces may be made up of several sclerites.

The typical number of segments in the insect body is about 20. This number is greatly obscured and reduced in most insects by the fusion of some of the segments and the degeneration of others. So that

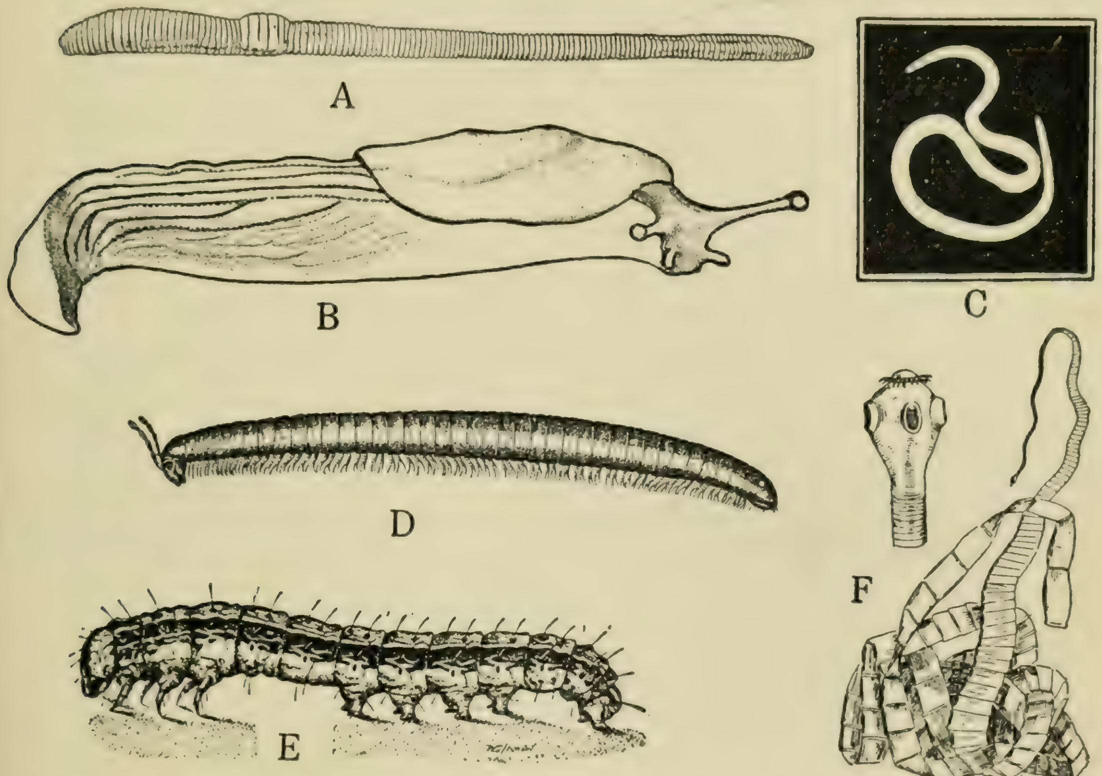

FIG. 45.—Six different kinds of animals often called "worms," that should be sharply distinguished. *A*, an earthworm, *phylum Annelida (from Sanderson and Jackson)*; *B*, a slug, *phylum Mollusca (redrawn after Lovett)*; *C*, a round worm, *phylum Nemathelminthes (from Herms)*; *D*, a millipede, *phylum Arthropoda, class Diplopoda (from U. S. D. A.)*; *E*, a caterpillar, *phylum Arthropoda, Class Hexapoda, (from U. S. D. A.)*; *F*, a tapeworm, *phylum Platyhelminthes*, the head greatly enlarged at the left *(from Jordan and Kellogg)*.

ordinarily one will recognize only from 8 to 12 obvious body rings in most insects (Figs. 36, *A* and 46).

The Body Regions of Insects.—Other animals besides insects have the body externally segmented, notably the true worms, thousand-legged worms, crayfish, and their relatives. The phylum Arthropoda, to which insects, spiders, crayfish, and similar creatures belong, differs from the true worms (phylum Annelida) by having a pair of jointed appendages on at least a part of the body segments. In this way we distinguish such things as caterpillars, maggots, and grubs (often called "worms," but really young insects) from the true worms such as the earthworm, and

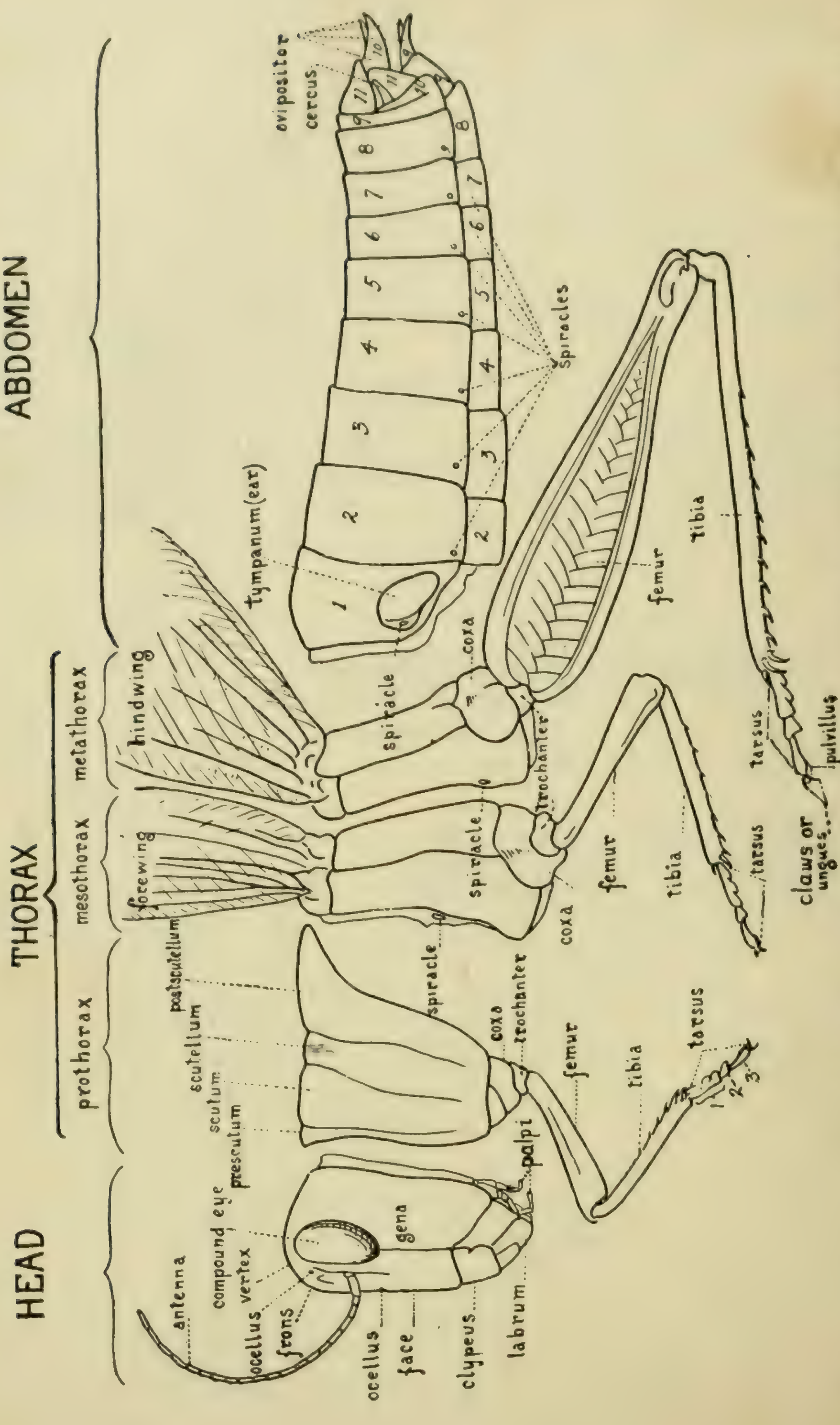

FIG. 46.—Outline of body of a grasshopper as seen from the side, dissected to show the three body regions and the parts of the body commonly referred to in books and bulletins. (*Slightly modified from Herms', "Medical and Veterinary Entomology."*)

from parasitic worms like the tapeworm. The latter have no legs (Fig. 45).

In the true insects, there are never more than one pair of jointed appendages on any body segment. Hence, even if the conjunctivæ are lost and the segments fused together, as in the head, we can usually tell how many segments are represented by noting the number of païred, jointed appendages present.

Six of the twenty segments of the insect body are fused into what we call the *head*. The next three segments comprise what is called the *thorax*, which is distinguished as *that part of the insect body which always bears the jointed legs, and the wings* if they are present. The remaining part of the body (typically ten or eleven segments) bears no jointed legs and is called the *abdomen*. We say, therefore, that the segments of the body of an insect are grouped into three *body regions*, known as head, thorax, and abdomen (Fig. 46). This is a further development of the specialization and division of labor spoken of in connection with the segmentation of the body. The head of the insect takes over the function of locating and taking in food, as well as most of the work of sensing danger and recognizing friends and enemies. The thorax practically always performs locomotion, while the organs of reproduction are borne by the abdomen. The one thing that marks off the thorax from the head and abdomen is that it bears the legs. Hence we find the thorax and determine its limits by finding where the six legs are attached, even in cases, like the beetles, where the thorax *appears* to end just back of the front legs. The three segments of the thorax are given distinctive names: the one bearing the first pair of legs is known as the *prothorax;* the segment bearing the middle pair of legs is the *mesothorax;* and the segment to which the hind legs attach is the *metathorax*.

The Legs of Insects.—The most characteristic single thing we can name for insects is the presence of three pairs of jointed legs. These are practically always present in adult or mature insects, and generally present in all other stages. However, a good many maggots, grubs, and other larvæ are entirely legless (see Figs. 451, 517, *b* and 536). Some insect larvæ, notably the caterpillars, have in addition to the six pairs of jointed legs on the thorax, anywhere from two to eight additional pairs of fleshy, *unjointed* projections on the abdomen, which are used as legs and are known as *prolegs* (see Figs. 82 and 83, *A*, *F*).

Insects are the six-legged Arthropods. It is this character that has given them their class name Hexapoda (meaning six legs). The spiders, mites, and ticks (Figs. 88 to 90) have four pairs of legs. The crayfish (Fig. 93), lobsters, crabs, and their relatives have five pairs of walking legs. The hundred-legged worms (Fig. 87) have a pair to each body segment, anywhere from 12 to 60 pairs in all. While the thousand-legged

worms (Fig. 45, *D*) have two pairs to each apparent segment, sometimes as many as 173 pairs.

No one can study active insects long without being impressed by the extensive use they make of their legs. In insects the legs perform many of the functions for which we would use our hands, though sometimes the mouth parts are used for digging, carrying, fighting, and the like. In addition to walking and jumping, insects often use their legs for digging, grasping, feeling, swimming, carrying loads, building nests, and cleaning parts of the body. The cricket and katydid have "ears" on their front legs (Fig. 47, *A*).

Perhaps there is something significant in the number of legs that we find in this most abundant group of animals. If we study the movements of the legs, we find that the insect does not move the three on either side together and alternately with those on the other side; nor does it move the two of any pair in unison. Instead they go in tripods, the middle one of either side being raised and advanced about the same time as the front and hind ones of the other side. While these three are being advanced, the other three are supporting the body. Since three supports is the smallest number that will give a stable equilibrium, we see that insects, unlike two-legged and four-legged animals, are in a state of stable equilibrium, whether standing or moving. This requires less muscular effort and practically eliminates that hazardous period that many animals undergo while learning to walk. As to a larger number of legs we need only quote the following ditty:

> A centipede was happy, quite,
> Until a toad in fun
> Said, "Pray, which leg moves after which?"
> Which raised her doubts to such a pitch,
> She fell exhausted in the ditch,
> Not knowing how to run.

All insect legs are made up of five parts and these parts always occur in the same order. Beginning next to the thorax, the names of the parts are (Figs. 46, 47 and 53):

Coxa (plural coxæ)
Trochanter (plural trochanters)
Femur (plural femora)
Tibia (plural tibiæ)
Tarsus (plural tarsi).

These names are constantly used in describing and determining insects, and they should be learned once for all. All of these parts are single segments except (*a*) the tarsus, or "foot," which varies from one to five segments (besides the claws and pads at the end of the leg, which are not counted as segments); and (*b*) the trochanter, which in a few cases,

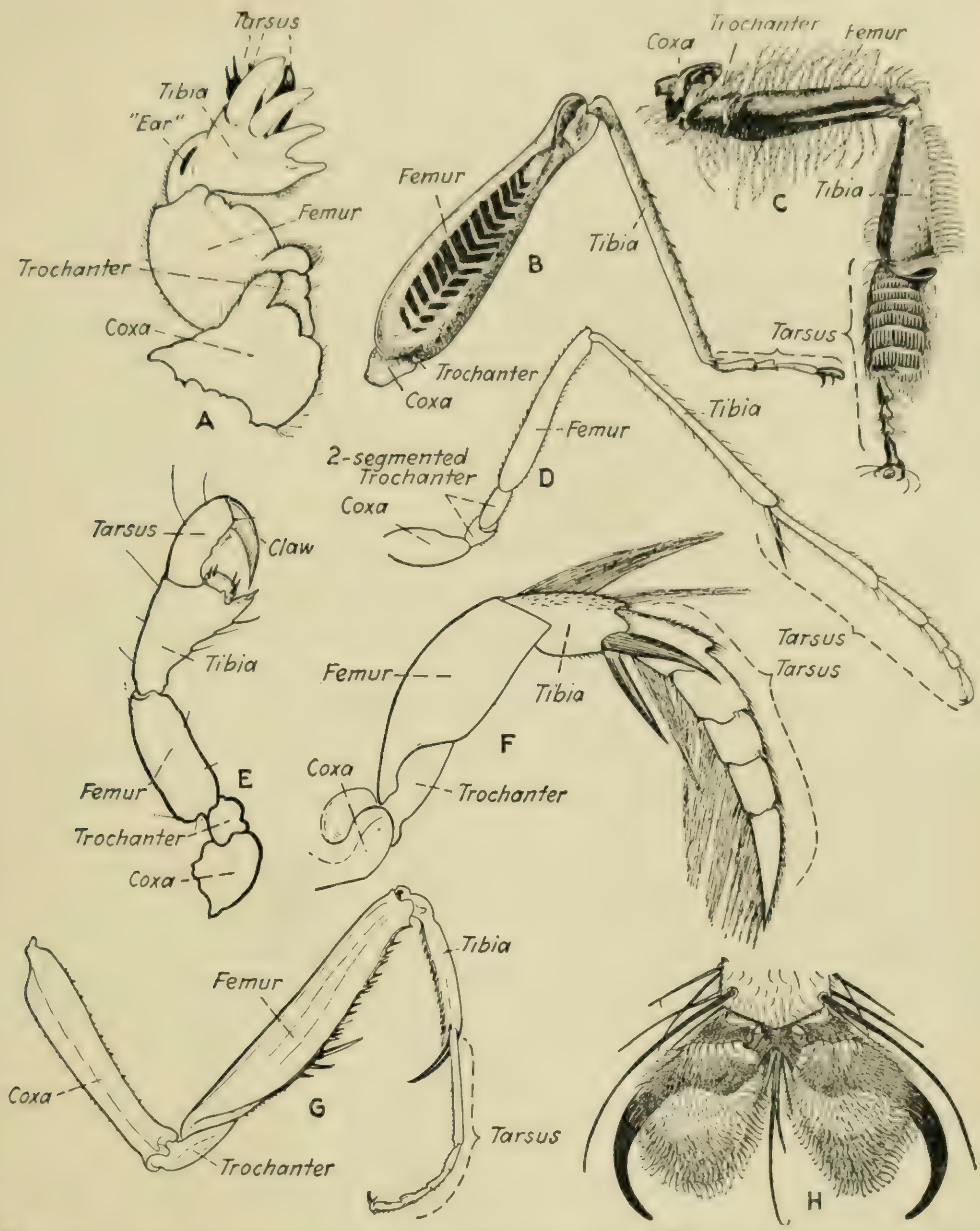

FIG. 47.—Legs of insects showing modifications for different functions. *A*, digging leg of a mole cricket. Note the rakelike tibia with the three-segmented tarsus beneath it; also the slitlike "ear" or tympanum toward the base of the tibia. *B*, jumping leg of a grasshopper (*from Univ. Kansas*). *C*, hind leg of worker honeybee adapted for assembling and carrying food substances; the rows of regular hairs on the basal segment of the tarsus are used for gathering pollen; the large marginal bristles of the tibia form, on the side opposite that shown, the pollen basket for carrying pollen to the hive (*from Cheshire*). *D*, walking leg of an ichneumon wasp. Note the two-segmented trochanter. *E*, clinging leg of the hog louse. Note the one-segmented tarsus with a single claw adapted for clinging around a hair. *F*, swimming leg of a predaceous diving beetle. Note the numerous long hairs used in rowing and the coxa which flattens out on the body wall. *G*, grasping leg of a praying mantis showing the very long coxa to extend the reach and the spiny femur and tibia between which insects are caught to be devoured. *H*, foot of the common house fly, showing claws, pulvilli and the tenent hairs that make it possible for flies to walk upside down (much magnified). (*H from Kellogg's "American Insects;" A, B, D, E, F, G, original.*)

notably the parasitic wasps, has two segments (see Fig. 47, *D*). The femur and the tibia are usually much longer than any other segments in the leg, and of these the one nearer the body, and usually the thicker one, is the femur; the slenderer, outer one is the tibia. Between the femur and the body there are always two (rarely three) small pieces, the one nearest the femur being the trochanter, and the one next the body the coxa. All that part of the leg beyond the end of the tibia is the tarsus. The tarsus is the only part of the leg that is placed flat on the ground when the insect is walking, though the end of the tibia often has prominent spines that help to get a footing. The tarsus usually bears two sharp, curved hooks or claws, and some complicated pads on its terminal segment, that are very important in locomotion. For example, in the house fly there are many microscopic hollow hairs on these pads through each of which a sticky substance exudes that enables the fly to walk upside down and up very smooth surfaces (Fig. 47, H).

The Wings of Insects.—A characteristic of insects that we may be sure has been of very great advantage in their struggle for existence is the possession of wings. Wings enable insects, (*a*) to forage far and wide to find suitable food; (*b*) to flee quickly from enemies and other dangers; (*c*) to disperse widely and intimately to find mates and lay their eggs; (*d*) often to select nesting sites not accessible to many of their animal enemies.

Insects are the only winged invertebrates. That is to say, if one finds an animal that has wings and does not have a backbone one may be sure it is an insect. Wings have been developed also in two groups of vertebrate animals, the birds (Aves) and the bats (Mammalia). But insects were almost certainly the first "flying machines," because we know from fossil records that they were present on the earth in the Silurian age, long æons before either birds or bats made their appearance upon our globe.

While adult insects regularly have six legs, the number of wings varies among the different kinds. Insects never have functional wings until they are full-grown or adult, and many adult insects do not have wings. Silverfish and springtails represent wingless-insect groups, whose ancestors apparently never had wings. Others, such as fleas and lice and certain ants and aphids, are considered to be degenerate forms whose distant ancestors possessed wings which have been lost in adaptation to a more quiescent life in the ground or on the bodies of animals. Some of the beetles which possess wings have not used them and they have become atrophied and useless. Other insects, such as termites and certain ants, break off or tear off their wings after a single nuptial flight and before beginning their life in the soil. No insect has more than four wings, or two pairs. This is the typical number. Some insects have only one pair. A good many are wingless throughout life.

The wings, like the legs, are always attached to the thorax, the front pair to the mesothorax and the hind pair to the metathorax (Figs. 44, *B*, 46, and 53). When one pair only is present (Fig. 36), it is the first pair, and it is borne by the mesothorax. We see thus that the thorax has all the organs of locomotion. This is ideal because it is near the center of mass of the body.

The wings of an insect are remarkably different structurally from those of a bird or bat. They contain no bones, muscles, feathers, nerves, or blood vessels, and usually no joints. They are simply thin sheets of parchment-like cuticula that are moved by the action of muscles attached to the base of the wing, inside the body wall.

The wings develop, as anyone can easily determine by examining a young grasshopper or bug, a moth newly emerged from its chrysalis, or

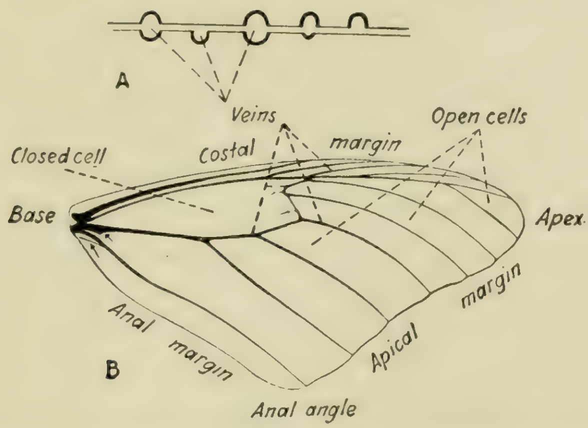

Fig. 48.—Front wing of the monarch butterfly, showing names applied to various parts of an insect wing. (*Original.*) *A*, diagrammatic cross-section of an insect wing to show how it is formed of two membranes and how the veins develop as hollow rods by the thickening of one or both membranes along certain lines. (*Redrawn after Woodworth.*)

a teneral fly, each as a hollow sac folded out from the body wall (Fig. 81). Promptly after the insect breaks out of its pupal or last nymphal skin these wing sacs enlarge and their walls flatten together and unite, so that the upper and under walls of the sac become fused and indistinguishable from a single membrane. They fuse closely in this way, except along certain lines where the two walls remain separated slightly and become thickened, to make a kind of framework of hollow ribs, between which the wing membrane stretches. The hollow linear ribs (Fig. 48) which make up the framework of the wing are known as *veins*, though they have nothing to do with the circulation of the blood. The areas, of various shapes, enclosed between the veins are called *cells; closed cells* if the area is entirely surrounded by veins, *open cells* if the area extends to the wing margin without an intervening vein (Fig. 48).

In outline (Fig. 48) the wings are often somewhat triangular. The front side of the triangle is known as the *costal margin*, and the outer side the *apical margin*, while the third side is called the *inner* or *anal*

margin. Generally the veins are heavier or more closely placed toward the costal margin, since the greatest stress during flight is on this area of the wing.

Wings are very important structures in the classification of insects. This is because they vary so widely in form and appearance in different groups. As we shall learn later, most of the order names of insects end in *ptera*, meaning wing. Thus the Diptera (flies) are the "two-winged" insects, the Coleoptera (beetles) are the "sheath-winged" insects, the Lepidoptera (moths and butterflies) are the "scale-winged" insects, the Hemiptera (true bugs) are the "half-winged" insects, the Hymenoptera (wasps, bees) are the "membrane-winged" insects, and the Orthoptera (grasshoppers, etc.) are the "straight-winged" insects.

There is a great range in size of wings from those of the largest known grasshoppers and moths, whose two wings spread 10 or 11 inches, to those of minute egg parasites which barely expand $1/100$ inch from tip to tip. A large wing does not necessarily mean that its possessor is a rapid flier. Indeed, in general the swiftest flying insects are those with small- to moderate-sized wings. The rapidity with which the wings beat is a much more important factor in the speed of flight. Butterflies in flying commonly beat the wings at about 9 strokes a second; dragonflies about 28 strokes a second; while other insects like the honeybee and the house fly vibrate their wings much more rapidly—so fast that they become invisible.

The Antennæ of Insects.—The way in which segmentation of the body facilitates division of labor is well shown in the paired jointed appendages on the heads of insects. These appendages of the head arise during embryonic development in exactly the same way as the legs, and for a time are indistinguishable from them. But in the active insect these appendages have become greatly differentiated for several distinct functions. One group of them comprises the mouth parts which are discussed more fully in Chap. V. Another pair of appendages, homologous with the legs, has become modified to form the "feelers" or "horns," or, as they are properly called, the *antennæ* (Figs. 46 and 49).

None of the higher animals has anything to compare with the antennæ of insects and their relatives. With them various insects feel their way, detect danger, locate their food, find their mates, and, at least in some cases, use them to communicate with others of their own kind, (*e.g.*, the ants); or bear end organs of smell (as in the flies); or use them in hearing (*e.g.*, as the male mosquito). A pair of long, flexible, highly sensitive "feelers," with which the insect can sound out the environment ahead, must be of very great advantage to these active animals. Most insects show great distress and sometimes helplessness when the antennæ are removed or injured.

All true insects have one pair of antennæ. This is a useful distinguishing mark; for the spiders, mites, ticks, and scorpions have no antennæ,

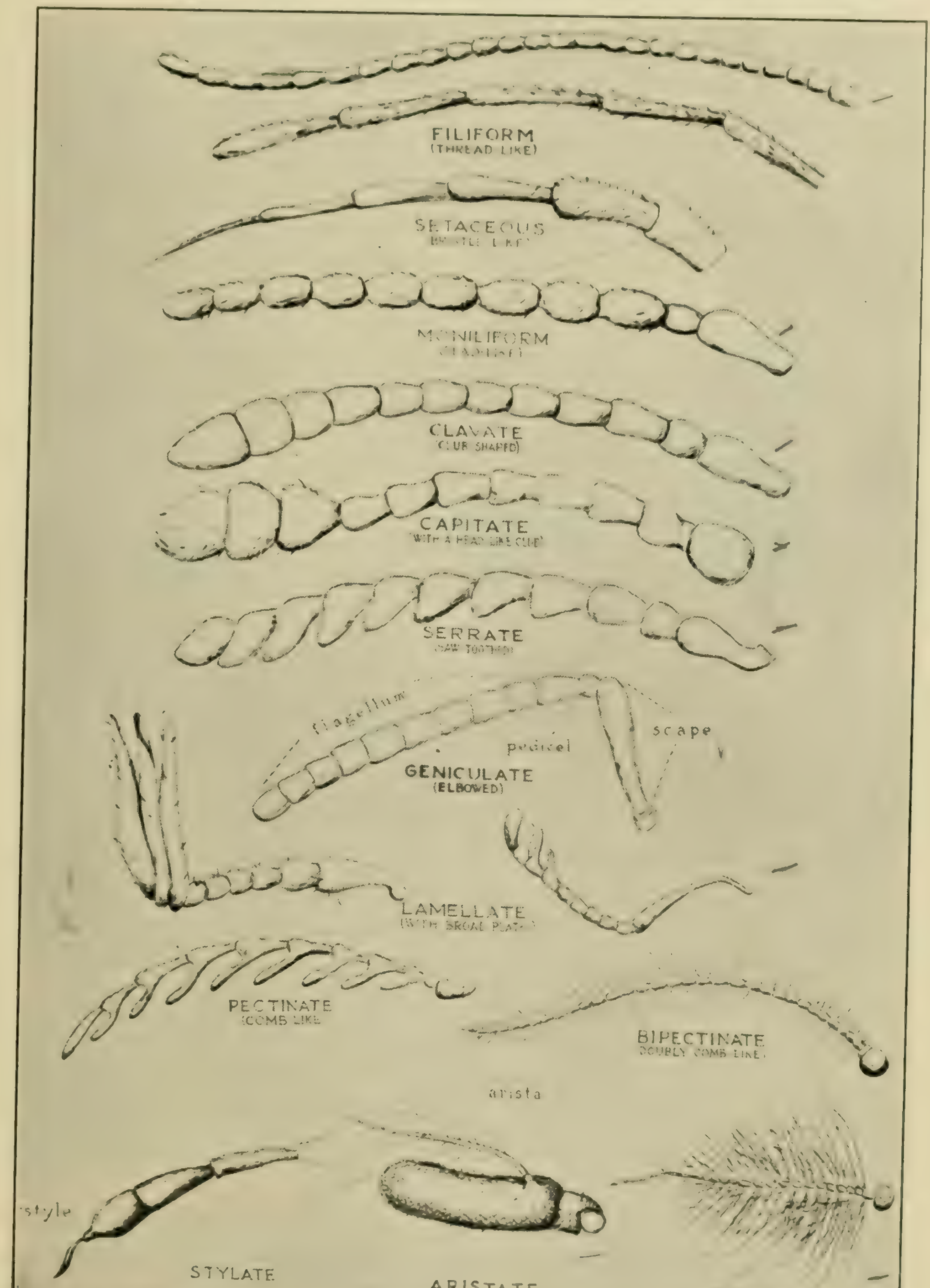

Fig. 49.—The commoner types of insect antennæ with the names applied to each type. (*Redrawn from various sources.*)

the crayfish, lobsters, and crabs have two pairs, while the centipedes and millipedes agree with the insects in having one pair.

Types of Antennæ.—The antennæ of insects vary greatly in size and form, and are much used in classification. The following special names have been applied to

certain of the common types (Fig. 49). A *filiform* or thread-like antenna is one in which all the segments are of about the same thickness and without prominent constrictions at the joints. A *moniliform* antenna is one made up of somewhat globular segments, with prominent constrictions between them, the whole suggesting the shape of a string of beads. A *setaceous*, or bristle-like, antenna is characterized by a noticeable decrease in the size of segments from the base to the apex, so that the antenna tapers from a rather thick base to a very slender tip. A *clavate*, or club-shaped, antenna enlarges gradually toward the tip, the segments near the end being larger than those near mid-length. An antenna in which the enlargement toward the tip is more abrupt and greater than in the clavate type, is called *capitate* or knobbed. If the enlargement at the end is almost entirely toward one side from the axis of the antenna and forms broad, somewhat flattened plates, we call the antenna *lamellate*. Sometimes all of the segments show projections to one or more sides. If the segments have short triangular projections to one side we call the antenna *serrate* or saw-toothed. If these side projections are long, the antenna is said to be *pectinate* or comblike. Sometimes each segment has two or even three such projections, which form two or three rows of teeth along the sides of the antenna, when it is called *bipectinate* or *tripectinate*. An antenna which has whorls of hairs coming off at or near the joints is called *plumose* or plumelike. In many of the flies, the antennæ bear on the upper side of the third and last segment a heavy bristle known as the arista; and this kind of antenna is called *aristate*. A similar bristle or appendage at the end of the antenna is called a *style*, and such an antenna is said to be *stylate*. A *geniculate* antenna is one that has a sharp bend like a flexed arm.

The Eyes of Insects.—Insects have eyes of very complicated structure and of at least two very distinct kinds. Yet we believe that vision in most insects is poor, and probably subordinate to smell and touch as a guide to them in their reactions to the environment.

The two kinds of eyes are called *compound eyes* and simple eyes or *ocelli* (Fig. 50). Typically there are two compound eyes and three simple eyes. The simple eyes are so very small as to require careful examination to find them. They are often arranged in a triangle on the head, somewhere between the compound eyes. In butterflies and moths there are only two ocelli, one near the base of each antenna. In many insects there are no ocelli. Larvæ, such as caterpillars, maggots, and grubs, never have compound eyes, though they may have simple eyes, from one to six or more on each side of the head (Fig. 54). Nymphs, the young of true bugs, grasshoppers, and the like, do have compound eyes (Fig. 79).

The compound eyes are usually the most conspicuous objects on the wall of the head. They are convex, round, oval, or kidney-shaped areas, one on each side. They usually appear shiny and suggest their function even at a glance. But when examined through a microscope they are found to be hardly eye-like at all. There are no eyelids or eyelashes protecting a delicate moist surface, as in the vertebrate eye; but the hard resistant cuticula of the general body wall continues without a break across the surface of the eye. It is, however, transparent over the eye surface, and admits the light; in this respect being something

like a window fixed in the wall of the otherwise dark skull-case, a window composed of very many minute hexagonal panes fitted closely together (Fig. 51). Each of these hexagonal areas is called a *facet*, and is the exposed face of an independent lens (*cornea*). Ants have from 50 to 400 facets or corneæ in each eye; the house fly has about 4,000 to each eye; a swallowtail butterfly, 17,000; while in certain of the sphinx moths (Folsom) and dragonflies (Tillyard) more than 50,000 facets occur in the two eyes. (See also p. 99.)

While most insects have very complicated organs of vision, there are some kinds that appear to be entirely blind.

Fig. 50.

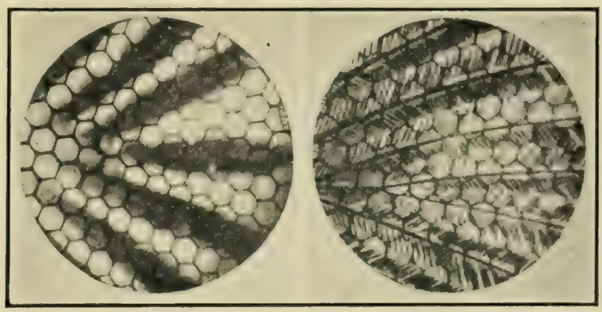

Fig. 51.

Fig. 50.—Head of a fly, *Didea fasciata* Macq., dorsal view, showing the large compound eyes which occupy the entire sides of the head; between them the three minute simple eyes or ocelli arranged in a triangle; and the aristate antennæ. This is a female fly; many male flies have the compound eyes touching each other on top of the head. Much enlarged. (*From Metcalf, in the Ohio Naturalist.*)

Fig. 51.—Photomicrographs taken through the cornea of a fly. Note the honeycomb-like margins ("sash") which divide the cornea into a number of hexagonal facets ("panes"). In one case the object photographed is extremely close to the eye, in the other case moved a slight distance further from the eye. (*From Howes' "Insect Behavior," courtesy Richard G. Badger.*)

Summary

In this discussion of the structures that adapt insects for so successful a competition with other animals, most of their *distinguishing characteristics* have been given; that is, the structural peculiarities that serve to separate them from all other animal groups. These may be summarized as follows:

1. Insects have three pairs of legs.

2. Insects have usually two pairs of wings when adult, sometimes only one pair, although many species are wingless.

3. Insects have a segmented body.[1]

4. The segments are grouped into three body regions known as head, thorax and abdomen.

5. Many of the segments bear a pair of jointed appendages.[1]

[1] These characteristics are shared with the other classes of the phylum Arthropoda (see pp. 106 and 162).

6. The head is provided with a single pair of antennæ.

7. Insects usually have a pair of compound eyes when adult, and sometimes simple eyes in addition.

8. The body has a chitinous exoskeleton instead of a bony endoskeleton.[1]

9. The body is bilaterally symmetrical.[1]

[1] These characteristics are shared with the other classes of the phylum Arthropoda (see pp. 106 and 162).

CHAPTER IV

THE INTERNAL ANATOMY AND PHYSIOLOGY OF INSECTS

A living insect performs all of the functions that are common to animals; and, so far as we can determine, none that are peculiar to insects, that is, none that are not performed also by the body of man or any other animal. The smallest insects are as perfectly formed in the structure of tissues and organs as man or an elephant. Few, if any, other animals have so complex an organization in so small a body.

The more important functions, together with the principal organ systems that perform them, may be listed as follows:

Functions	*Organs*
1. Ingestion	Mouth parts and pharynx
2. Egestion	Rectum and anus
3. Digestion, absorption, and nutrition	Alimentary system
4. Excretion	Excretory system
5. Secretion	Glands
6. Respiration	Respiratory system
7. Circulation	Circulatory system
8. Sensation, conduction, and coordination	Nervous system
9. Motion and locomotion	Muscular system
10. Reproduction	Reproductive system
11. Growth and development (discussed in Chap. VI).	
12. Protection	Various organs and habits

Metabolism

Living animals of most kinds, and insects in particular, are noteworthy for their great activity, the continual changes of their physical bodies and their ability to do "work." This work involves especially moving about to secure food and congenial surroundings, to escape enemies, to find mates, to construct nests, and to lay eggs for another generation. The ability to do work depends upon the possession of energy. This is secured from food substances in which energy from the sun has been stored by green plants. *Metabolism* is the term applied to all the chemical changes taking place in the living body. It has two phases: (*a*) *anabolism*, a building-up process, which begins with digestion and reaches its climax after the assimilation of the digested foods and their synthesis into various bodily *secretions* and the complex proteid compounds which make up *protoplasm*, the living substance. The complex and unstable

protoplasm is continuously being attacked by breaking-down reactions (especially oxidation), which are known collectively as (*b*) *katabolism.*

Katabolism is a very important process, for through it only can the energy essential for all life activities be released from the food in a usable form inside the body. Katabolism results in the formation of wastes or by-products. Some of these (for example, water) may be used again by the body. Gaseous wastes, such as carbon dioxide, are removed by the tracheæ in the process known as respiration (see below). Other wastes are taken by the blood and carried in solution until they are eliminated by the process known as excretion (see below).

Ingestion and Egestion.—The *ingestion* or taking in of foods is treated in the chapter on mouth parts of insects (Chap. V). Most food materials when taken into the alimentary canal cannot pass through its walls into the blood and be carried to the various tissues requiring them, until they have undergone certain modifications known as *digestion,* which render them soluble or absorbable. Much of the material swallowed is indigestible and is *egested* from the alimentary canal, never having been a part of the living body of the insect. This act of voiding material that has not been digested (*egestion or evacuation*) must not be confused with *excretion,* discussed later. Often poisons designed to kill insects fail because, even though eaten, they pass unchanged through the body. It is an interesting fact that certain insects, such as parasitic wasps and the honeybee, while young, have no connection between the mid-intestine and the hind-intestine and cannot void any excreta until as adults they leave the body of the host or the brood cells where their youth was passed.

Digestion, Absorption, and Nutrition.—The digestive processes of insects have never been adequately studied. Apparently insects have no organs like the liver and pancreas of higher animals. Yet some insects digest substances that the human system cannot assimilate, such as dry wood (cellulose) and wool. And others may develop on a pure diet of substances such as black and red pepper, ginger, ergot, or tobacco that to us would be inacceptable or poisonous. In some cases (see termites, p. 739) it appears that the digestion of substances like cellulose is really brought about by minute animals, protozoa, that make their home in the alimentary canal of the insect. Without these protozoa the insects cannot live. In such cases the insect may live on the excreta of the protozoa, or the latter may function to utilize atmospheric nitrogen, an essential element that is lacking in the cellulose.

The digestive enzymes produced in the several parts of the alimentary canal and in the various insect species may be expected to vary greatly in correlation with the nature of the food. In some species the secretion of the salivary glands (Fig. 53) probably converts starch into glucose, as does the saliva of man. Other enzymes produced by the epithelial

cells of the canal walls or of the gastric cæca (Fig. 53) act upon the food substances as the peristaltic movements of the canal forces the pabulum slowly along. Gradually a portion of the material consumed is rendered soluble and absorbed through the canal walls into the blood stream, to be carried to all parts of the body.

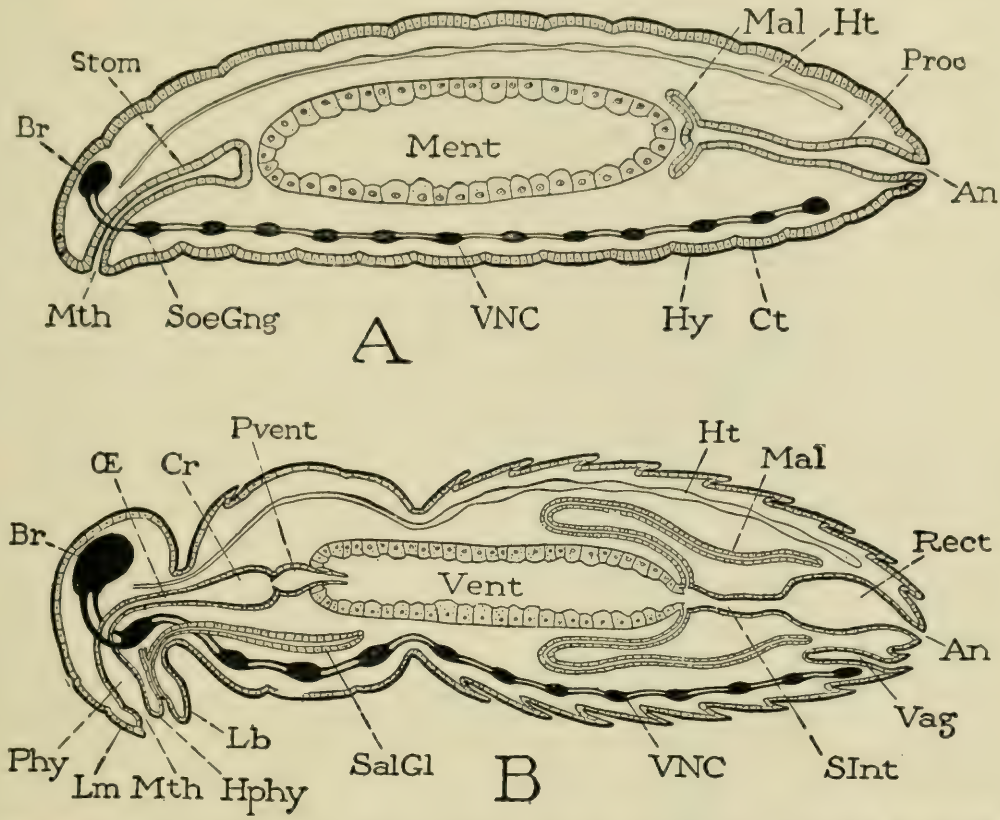

FIG. 52.—Diagrammatic sagittal sections of the body of an insect to show the arrangement of the principal organs and the formation of the alimentary canal. *A*, section of an insect in the embryonic stage, showing the anterior invagination of the ectoderm which forms the mouth (*Mth*) and fore-intestine or stomodeum (*Stom*); the posterior invagination which forms the anus (*An*) and hind-intestine or proctodeum (*Proc.*); and the endodermal development of the mid-intestine called the mesenteron (*Ment.*). *B*, section of a mature insect, after fore- and hind-intestines have united with the mid-intestine to form a complete canal. The fore-intestine has differentiated to form the pharynx (*Phy*), œsophagus (Œ), crop (*Cr*), and gizzard or proventriculus (*Pvent.*). The hind-intestine has differentiated into small intestine (*S. Int.*) with the Malpighian tubes (*Mal*) arising from its anterior extremity, and rectum (*Rect*). The mesenteron has become the stomach or ventriculus (*Vent*) of the adult. *An*, anus; *Br*, brain; *Cr*, crop; *Ct*, cuticula; *Hphy*, hypopharynx; *Ht*, heart; *Hy*, Hypodermis; *Lb*, labium; *Lm*, labrum; *Mal*, Malpighian tubules; *Ment*, mesenteron; *Mth*, mouth; *Œ*, œsophagus; *Proc*, proctodeum; *Pvent*, proventriculus; *Rect*, rectum; *SalGl*, salivary gland; *SInt*, small intestine; *SoeGng*, subœsophageal ganglion; *Stom*, stomodeum; *Vag*, vagina; *Vent*, ventriculus; *VNC*, ventral nerve cord. (*From Snodgrass, "Anatomy of the Honeybee."*)

The alimentary canal of insects is a tube leading from the mouth to the anus at the tip of the abdomen, so that the structure of the insect has aptly been likened to a tube within a tube, the outer tube being the body wall, the inner tube the alimentary canal. The space between these two tubes is called the body cavity, blood cavity or *hemocœle*. In

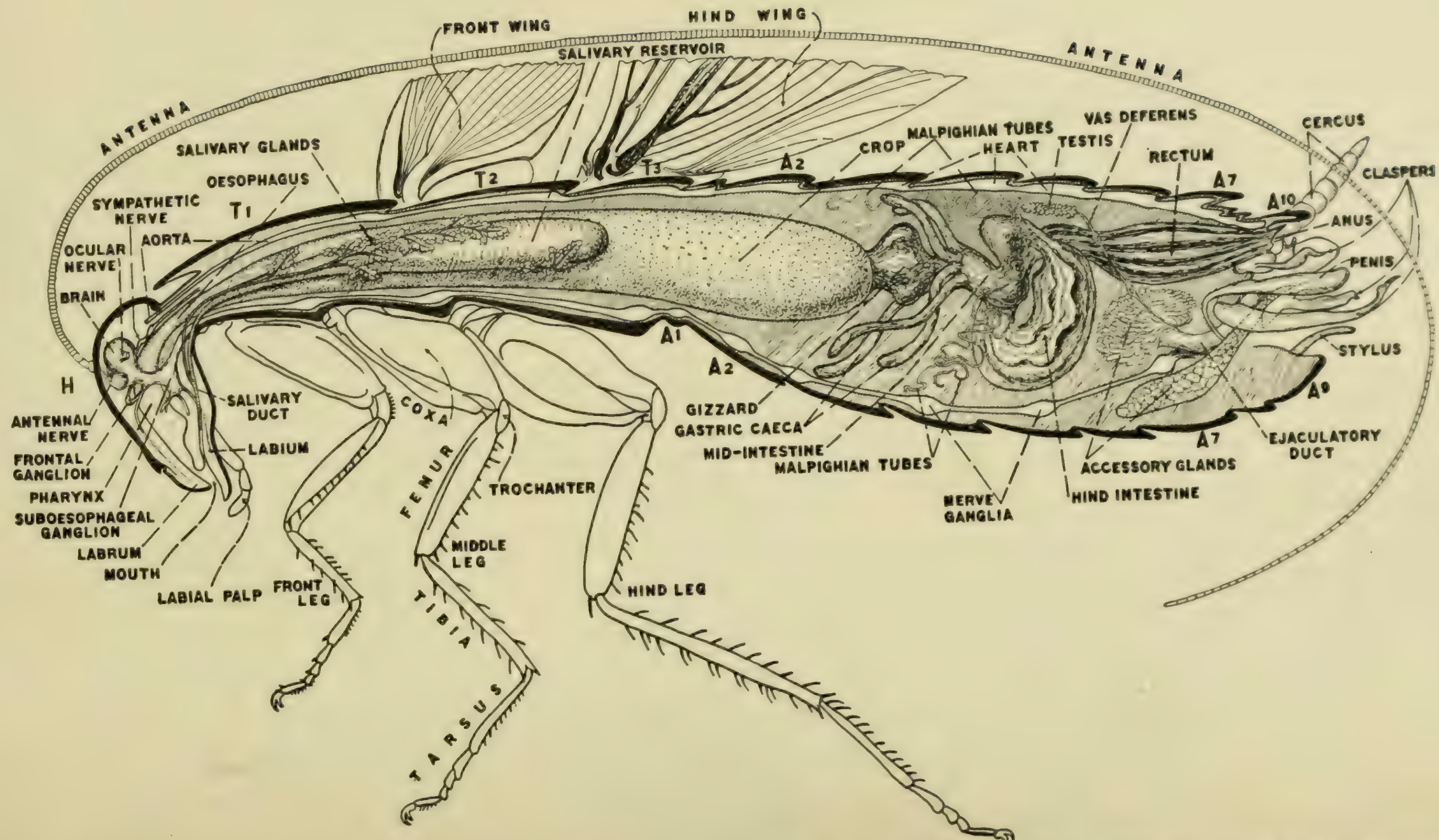

FIG. 53.—Sagittal section of the body of a roach, to show especially the internal anatomy of digestive, reproductive, nervous, circulatory and excretory systems. None of the tracheæ are shown. *H*, head; T_1, prothorax; T_2, mesothorax; T_3, metathorax; A_1 to A_{10} first to tenth abdominal segments. (*Original; drawing by Antonio M. Paterno; in part after Miall and Denny.*)

insects it is largely filled with blood. The length of the alimentary canal and the complexity of its structure depend on the food habits of the insect, and vary greatly.

During embryonic development, the alimentary canal forms in three sections (Fig. 52): the *fore-intestine* and the *hind-intestine* grow as invaginations from the outside, and consequently are lined with cuticula similar to that on the outside of the body. This cuticular lining performs an important function in some insects, such as the grasshoppers, in which it is developed, in the region of the proventriculus or gizzard, into strong teeth. The cuticula of the fore- and hind-intestines is molted each time the external skin is shed. The *mid-intestine* develops internally (Fig. 52, *Ment.*) and consequently lacks the cuticular lining.

In some insects the fore-intestine consists only of the mouth cavity or *pharynx* (Fig. 52, *Phy*) and a straight, thin-walled tube, the *œsophagus* (Œ) leading back to the *stomach* (*Vent*). In other kinds, the fore-intestine becomes greatly specialized. The pharynx, especially of insects having piercing, siphoning, or sponging mouth parts, is generally developed into a pump or sucking device, closed by the elasticity of its cuticular lining and by muscles in its walls, and opened by muscles extending from these walls to the inside of the skull case (Figs. 64 and 68). The far end of the œsophagous is often enlarged into a *crop* (Fig. 52, *Cr* and Fig. 53) where food is held temporarily, and a *gizzard* (*Pvent*) for grinding and straining the food.

Between fore-intestine and hind-intestine, the *mid-intestine* (Fig. 52, *Ment*, *Vent* and Fig. 53) is developed internally from the embryonic endodermal tissues. This tube eventually meets and connects with the fore- and the hind-intestine to make a continuous canal. The mid-intestine can be recognized by the absence of a cuticular lining. Instead, the cells lining it are large, active cells that secrete digestive juices. Their number, and accordingly the amount of the secretion, is often increased by outpocketings of the wall into short or long tubes known as *gastric cœca* (Fig. 53), the number of which varies greatly. It seems likely that it is in the region of the mid-intestine that the poisons known as stomach poisons chiefly attack insects that have swallowed them.

Excretion.—The beginning of the hind-intestine is marked by the attachment of a variable number of tubes, often very long and slender, that are known as *Malpighian tubes* (Fig. 52, *Mal*, and Fig. 53). These are believed to have a function similar to the kidneys of higher animals, in sorting out from the blood stream the waste organic compounds that result from katabolism. The tubes are closed at the free end and have a *lumen* that is surrounded by the secreting cells. Their cavities or lumina open into the cavity of the hind-intestine. They differ from the kidneys of mammals, not only in form and in having no separate opening to the exterior, but also in the nature of the urinary products formed.

In the higher animals, these products (for example, urea) are soluble and are eliminated in solution as urine. In the insects, the excretory products are insoluble, and the Malpighian tubes pour their semisolid excretions (principally uric acid) into the hind gut, through which it is carried from the body with the feces.

Secretion.—The metabolism of insects results in the formation not only of the living protoplasm, but also of various chemical substances that serve a useful purpose in the body. Such substances are called *secretions*. Cells of the body that form secretions, or groups of such cells, are known as *glands*. Many of these glands are formed as in-foldings or other modifications of the hypodermis; others from the epithelium lining the internal surfaces of the body. Examples among the insects are the salivary glands which secrete saliva (including silk, p. 36). Scent glands, which give the odor to so many bugs, may be repellent or alluring. The repellent glands ward off enemies. The alluring glands doubtless serve an important function in recognition and communication among members of the same species or colony. For example, among bees and ants many of their seemingly intelligent acts may be accounted for by the recognition of tell-tale odors. Alluring glands, serving by the odor of their secretions to attract the opposite sex, occur on patches of peculiar scales (*androconia*) on the wings of male butterflies, or as tufts on the legs of the males, or have their openings near the tip of the abdomen of females. Hypodermal gland cells secrete the cuticular covering that forms the skeleton of the insect; also the waxy covering of scale insects (including lac, p. 42); also a moulting fluid used in casting old skins. The wax glands of the bees form a material used in making nests (p. 41). The tenent hairs of the fly's foot have already been described. The stings of Hymenoptera and the nettling hairs of catterpillars (p. 17) have poison glands associated with them. Doubtless there are many other glands in the body of the insect that secrete important enzymes, vitamines, and hormones necessary to regulate and control metabolism, but little study of this subject in insects has been made. The digestive, excretory, and reproductive glands are briefly discussed under those headings.

The fat body of insects (Fig. 54, *ad*) is an important group of cells that occupies much of the space between the larger organs in the body cavity. In these cells is stored fat, glycogen, and other nutrient substances not immediately required to maintain life. This store is drawn upon for the histogenesis necessary when an insect changes from larva to pupa and adult; for the development of the eggs of the adult female and as a source of energy to maintain life during periods of hibernation or other stressful times. Since no food is taken during the pupal stage, the most important function of the fat body seems to be to accumulate, during the feeding period of the larva, a sufficient reserve to furnish energy for the

metamorphosis to the adult. Rogers[1] states that the fat gives rise to glycogen during the pupal stage of the silkworm, which in turn becomes transformed into sugar by the time the adult stage is reached. In some insects, especially those that do not have Malpighian tubes, it is believed that the fat body serves as an important organ of excretion. The excretory products may be held as more or less permanent concretions in the fat body or discharged through the alimentary canal as a *meconium* when the adult emerges from the pupa (Imms).

Respiration.—Unlike the higher animals, insects have neither nostrils nor lungs. They breathe, not through the mouth or other openings on the head, but through a series of paired holes along the sides of the body which are called *spiracles* (Figs. 46, 54, 1, *s*, and 54, 6). These openings occur on thorax and abdomen, but not on the head; usually there are two pairs on the thorax and from six to eight pairs on the abdomen.

The spiracles lead into tubes called *tracheæ* (Fig. 55). The tracheæ from different spiracles connect with each other and divide and subdivide and continue into the minutest branches, called *tracheoles*, (Fig. 55, *tra*) which reach ultimately to every organ, tissue, and cell of the body. These branching tubes form an intricate network throughout the entire body, and carry the air directly to every part of the insect (Fig. 58, *t*). Through the thin walls of the tracheoles the living cells withdraw the oxygen necessary to respiration, by diffusion, and in the same manner the waste gasses that result from metabolism are returned to the tracheæ and so out through the spiracles.

The spiracles (Fig. 54, 6) are often guarded by hairs or plugs that serve to exclude foreign matter, and the trachea just within the spiracle has in some insects a valvelike device for closing it. The tracheæ, but not the tracheoles, are lined with cuticula continuous with that on the outside of the body. This takes the form of fine, spirally arranged threads (Fig. 55, *A* and *B*, *Tae*) that serve to keep the tracheal tubes from collapsing and that give to tracheæ a characteristically cross-striated appearance. This is sometimes useful in distinguishing even minute bits of insect tissue, which will contain tracheæ, from the tissues of many other animals which will lack it.

The sprays known as contact poisons (p. 240) and fumigants (p. 252) generally attack the insect by way of the respiratory system. To smother an insect it would probably be necessary to close practically all of the spiracles. Contact insecticides seldom kill by smothering except in the case of very small insects. The contact poisons are believed usually to penetrate through the tracheæ as gases or liquids and produce a chemical effect on the tissues which may result in the death of the insect. The highly resistant cuticular lining of these breathing tubes, though

[1] Rogers, "Textbook of Comparative Physiology," McGraw-Hill Book Company, Inc., 1927.

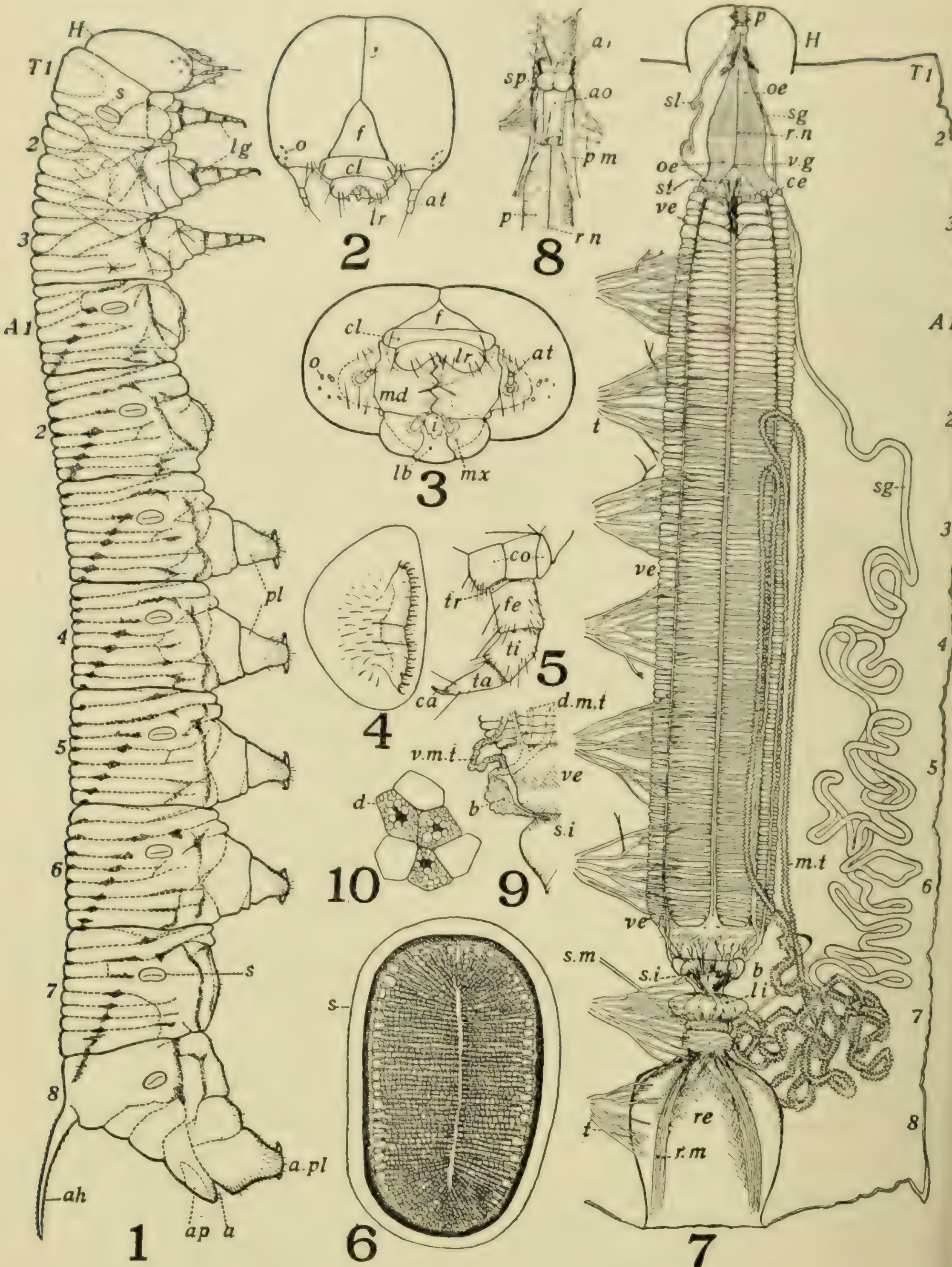

FIG. 54.—Anatomy of the tomato worm or hornworm. 1, Side view of entire larva; 2, front view of the head; 3, ventral view of the head to show chewing mouthparts; 4, a proleg, ventral view, showing crochets; 5, a true leg, or thoracic leg, front view; 6, a single spiracle, greatly magnified; 7, body of the larva opened from the dorsal side to show the alimentary canal. On the left side are shown the salivary gland and the terminal branches of tracheæ which enter the canal; on the right the silk gland and Malpighian tubes of that side of the body are represented; 8, the pharynx from above in the region of the brain; 9, enlarged view of the alimentary canal at the point where the bladder of the Malpighian tubule is attached; 10, a bit of the adipose tissue or fat-body. The

extremely thin, must offer considerable resistance to injury by insecticides, unless the latter penetrate to the minute tracheoles, which are not lined with cuticula.

Much is yet to be learned about the way in which insects respire; particularly how the air is forced the full length of the extremely delicate tubes. Some insects have been said to use certain of their spiracles for inhalation and others for exhalation. Folsom says that in insects inhala-

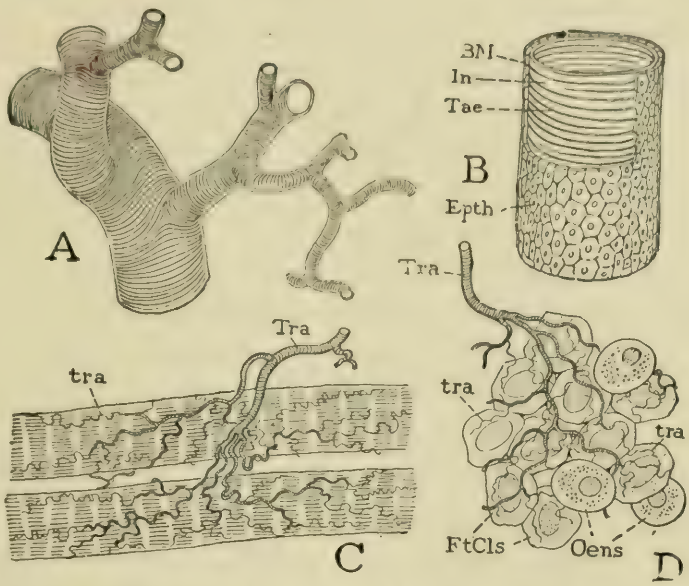

FIG. 55.—Structure and terminal branches of tracheæ. *A*, a piece of trachea showing characteristic cross-striated appearance due to spiral tænidia, and method of branching. *B*, structure of tracheal tube, showing epithelium (*Epth*) of flat cells, outer covering of basement membrane (*BM*), and inner cuticular lining or intima (*In*) with spiral thickenings of tænidia (*Tae*). *C*, tracheal branches (*Tra*) ending in tracheoles (*tra*) on muscle fibers. *D*, tracheation of piece of fat body, showing tracheoles on fat cells (*Ft Cls*), but not on œnocytes (*Oens*). (*From Snodgrass, "Anatomy of the Honeybee."*)

tion is a passive act; while exhalation requires muscular effort—the opposite of the condition in man.

Insects that live in the water either come to the surface to breathe at intervals, or carry air under water clinging to special parts of their bodies, or respire by means of gills. Insect gills (Fig. 102, *B*) are not usually blood gills like those of fish. The air that is taken in through the gill walls of insects usually enters tracheal tubes instead of being received

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following abbreviations are used: *A1* to *A8* abdominal segments one to eight; *a*, anus; *ad*, adipose tissue; *ah*, anal horn; *ao*, aorta; *ap*, anal plate; *a. pl*, anal proleg; *ar*, arched nerve; *at*, antenna; *b*, bladder of Malpighian tubule; *ca*, claw; *ce*, cæca; *cl*, clypeus; *co*, coxa; *d.m.t.*, dorsal Malpighian tubule; *e*, epicranial suture; *f*, front; *fe*, femur; *H*, head; *i*, spinneret; *lb*, labium; *lg*, leg; *li*, large intestine; *lr*, labrum; *md*, mandible; *mt*, Malpighian tubule; *mx*, maxilla; *o*, ocelli; *oe*, œsophagus; *p*, pharynx; *pl*, proleg; *pm*, pharyngeal muscle; *re*, rectum; *rn*, recurrent nerve; *rm*, rectal muscle; *s*, spiracle; *sg*, silk gland; *si*, small intestine; *sl*, salivary gland; *sp*, brain; *st*, part of sympathetic nerve; *T1*, *T2* and *T3*, thoracic segments, prothorax, mesothorax and metathorax, respectively; *t*, tracheæ; *ta*, tarsus; *ti*, tibia; *tr*, trochanter; *ve*, ventriculus; *v.m.t.*, ventral Malpighian tubule. (*From Peterson in Ann. Entom. Soc. Amer., Vol. V.*)

by the blood, as it is in fishes. Such gills are called tracheal gills in contrast with the blood gills of many other animals.

Circulation.—Tracheal respiration is much more direct than the method employed by the higher animals. In the higher animals the lungs serve as a place where the blood is purified by exchanging the waste gases of the body for oxygen. The red blood corpuscles carry these gases between the lungs and all other parts of the body. The blood of insects has no red corpuscles and has little or nothing to do with respiration. It is yellowish or greenish in color. Its chief function is nutritive, carrying food materials from the digestive system to all parts of the body.

Structurally, the circulatory system is very simple in insects, consisting of a single tube lying close under the body wall down the middle of the back. This tube (Fig. 52, *Ht*; Fig. 53; Fig. 58, *ao*, *h*), often called "the heart," is closed at the posterior end, but has small openings at regular intervals along the sides. The blood may enter these openings, but an arrangement of valves prevents its flowing back out of them.

When the tube contracts, the blood is forced forward to the region of the head where it leaves the tube and enters the general body cavity, that is, the space between the alimentary canal and the inner surface of the body wall. This cavity is filled with blood which, by the pulsations of the heart and some accessory organs, is kept flowing in more or less definite streams, over and about the viscera and out into all the appendages. As it bathes the alimentary canal, it receives by osmosis through the intestinal walls the digested food; as it passes muscles, glands, and other tissues, these nutrient substances from the food are given up to be transformed into protoplasm or secretions; and as it flows over the Malpighian tubes it gives up to them the waste products of metabolism which have not been passed out in gaseous form through the tracheæ.

Sensation, Conduction, and Coordination

It is one of the inherent characteristics of living substance to be sensitive or irritable to the various stimuli that act upon it and to respond by altering its behavior in some way. In all but the simplest of animals this is accomplished by a nervous system. Nerves are composed of cells, very highly specialized for sensation, conduction, and coordination. Each nerve cell is known as a *neuron*, and may be either a *sensory* (afferent) *neuron*, which conducts impulses inward from a sense organ; or a *motor* (efferent) *neuron*, which conducts impulses from the ganglia outward to muscles or glands. Each neuron has a body part, including the nucleus, from which extremely elongate, branched processes extend. The nervous system in insects is composed of groups of nerve cells arranged in small, white, compact masses known as *ganglia* (Fig. 53); of *connectives* that extend from one ganglion to another; and of *nerve*

fibers which extend from ganglia to all other organs of the body. These fibers connect eyes, antennæ, palps, and other sensitive parts of the body through sensory neurons to the ganglia, whence motor neurons carry the impulses to the muscles or glands. In this way, stimuli from the receptive end-organs are transmitted to the effective muscles or glands which respond by altering their behavior in some way.

The central nervous system in insects is composed typically of a series of ganglia which are connected by a double nerve cord running from end to end of the body (Fig. 52, *VNC*, Fig. 53). There are typically two ganglia, a right and a left, in each segment, but they are usually fused together and the double cords also fuse so that the typically ladder-like structure looks more like a thread with a knot in each body-segment. Except in the head, the whole system lies in the bottom of the body cavity along the ventral side of the body, instead of down the back as in vertebrates. In the head, a small mass of ganglia known as the *brain* (Fig. 52 *Br*, Fig. 53), lies above the œsophagus and another ganglionic mass, called the *subœsophageal ganglia* below the œsophagus. The alimentary canal (œsophagus) passes between the two connectives that extend from brain to subœsophageal ganglia.

The brain of an insect is a relatively much less important organ than the brain of a vertebrate. It is believed that in insects there is much less of associative processes, adjusting, coordinating, or deliberating, than in higher animals; much of the nervous activity being on a simple receptor-effector basis. As a result of this, each body segment exhibits considerable independence of other segments, its ganglion largely controlling the movements of the appendages to which its nerve fibers run. Insects that have had the brain entirely removed may live, walk, and fly for some time, though their movements may be erratic and not purposeful. The brain sends nerves to eyes, antennæ, and upper lip, the subœsophageal ganglion to the other mouth parts (see Fig. 53), and each other ganglion typically to the appendages of the segment in which it lies. In many adult insects, however, the ganglia from a number of segments fuse into one mass, especially in the thorax. When such a thoracic mass occurs it is usually highly sensitive to injury, and any mutilation of it results in death more promptly than similar injuries to the brain. In addition to the central nervous system just described, there is a small but rather complex *sympathetic system* (Fig. 53), which is thought to control the movements of the heart, the digestive system, and the spiracle muscles.

The Sense Organs of Insects.—The function of a nervous system is to acquaint the insect with changes in its environment. To do this it must have certain *receptors* (sense organs), which interpret or translate these changes (*stimuli*) into impulses that traverse the nerves and eventually produce a response in the muscle or gland to which they run. Some of the sense organs of insects are affected by light, others by pressure or contact

with other objects, some by sound waves, and others by chemicals in solution. The sense organs of touch are chiefly certain *sense hairs* on the surface of the body, that differ from ordinary hairs, or *setæ*, by having a minute nerve fiber running into them (see Fig. 43). The sense organs for the perception of chemicals are generally described as very thin-walled cones or plates covering a minute pore in the cuticula and kept moist by a secreting cell, the theory being that the contact of such a sense organ with *solid* parts of food or other chemical results in some of the latter's passing in solution through the thin wall of the cone or plate by osmosis and so stimulating the nerve ending in a manner which we call taste. If *gases*, or minute *drifting particles* of food or other chemicals, are dissolved on the moist end-organ, the result is similar, but we speak of it as smell. The sense organs of taste and smell are not so restricted in distribution as in higher animals. Organs of taste are generally thought to occur on palps, epipharynx, and hypopharynx; and organs of smell have been described as occurring on the palps, the antennæ, and in some cases on the cerci (Fig. 53), near the posterior end of the body.

Smell is probably a very important function among insects, and there seems every reason to believe that they detect odors that are imperceptible to us. This sense is important in locating foods, in locating suitable places to deposit eggs, and in finding mates. If the females of our larger moths, newly emerged from the cocoon, are exposed out-of-doors their odors usually attract males of their species from considerable distances. In one instance, 73 males of the cecropia moth were thus attracted by a single female exposed in a large screened cage, during one night.

Organs of Hearing.—Insects have no ears on the sides of the head. However, they do have various organs that are believed to serve for the perception of sound waves. The best known of these are the so-called "ears" of grasshoppers, which are conspicuous oval plates, *tympana*, one on each side of the first segment of the abdomen (Fig. 46). Over these areas the body wall is much thinned and apparently fitted to be set in vibration by sound waves. Internal to the tympana are certain complicated structures that doubtless serve to translate vibrations into impulses that traverse the auditory nerve to the thoracic ganglia. In crickets and katydids, a smaller tympanum is found on each front leg near the base of the tibia (Fig. 47, *A*).

Another very interesting organ of hearing has been described from the antennæ of the male mosquito. In the male mosquito, the whorls of hairs that come off from the antennal segments are much longer and more numerous than in the female. The second segment from the head is very large in the male and the rest of the antenna arises from a cup-shaped cavity on its outer, or *distal*, face (Fig. 49, *plumose*). The whorls of hairs are of different lengths, and vibrate to sound waves of different tones. It

is believed that these vibrations are transmitted through the large basal segment to the auditory nerve. Since the hairs vibrate extensively to tones of the same pitch as that of the hum made by the female mosquito in flight, the theory has been advanced that the male turns his head until the two antennæ are stimulated equally by such a sound, when, by flying straight ahead, he is able to find his mate.

Vision.—In the preceding chapter, p. 84, the external appearance of compound eyes with their many hexagonal facets was described. Each facet is the end view of a functionally independent eye unit, called an *ommatidium*, which runs inward like a tube or rod toward the center of the head (Fig. 56). From the inner end of each ommatidium a nerve fiber extends to the brain. The light admitted through the transparent cuticula at the outer end traverses the length of the "tube" and falls upon retinal or visual end-organs, which translate the wave lengths into stimuli that pass to the brain. It is believed that each ommatidium does not form an image of the whole object, but only preserves the intensity, pattern, and color of the light coming from the particular small part of the object that is in line with its long axis. Indeed, the several ommatidia, or "tubes," are usually so isolated from each other by pigment, that no light can pass from one to the other. The combined effect of thousands of such minute areas of light and shade makes the stimulus that the insect recognizes as the object before it. This is called "mosaic vision" and may be thought of as something like a cut-out picture puzzle; each unit of the puzzle, with its particular areas of light and shade, meaningless in itself, but when properly fitted to the others forming an image (Fig. 51).

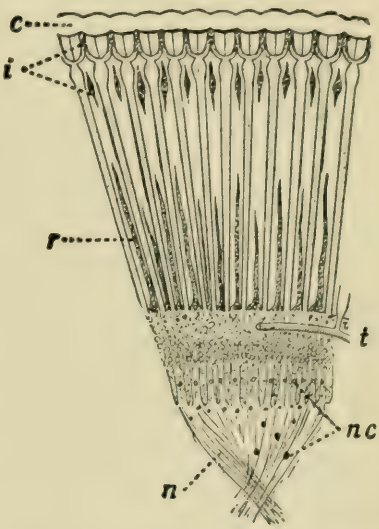

FIG. 56.—Portion of the compound eye of a blow-fly (*Calliphora vomitoria*) in radial section. *c*, cornea which is modified cuticula; *i*, iris pigment; *n*, nerve fibers leading to the brain; *nc*, nerve or retinal cells; *r*, retinal pigment; *t*, trachea. (*From Folsom's "Entomology" after Hickson, courtesy P. Blakiston's Son & Co.*)

We really do not know how well an insect can see with such eyes. They are sometimes so big and bulging that the insect must be able to see in front of it, to each side, above and below, and even to some extent behind. On the other hand, it cannot move its eyes, it cannot focus them upon objects at various distances, and of course it cannot close them. In all probability, the closer an object, the better it is seen, because more of the ommatidia will cover an object close at hand than one far away. It is believed that the compound eye is especially good at detecting objects in motion, because different independent ommatidia are stimulated in succession.

The *ocelli* or simple eyes are of several kinds, but all agree in differing from the compound eyes in having a single *cornea*, or shining convex lens, through which light is thrown upon retinal or visual cells. Such an eye, in which the shape of the lens and the distance from lens to retina is fixed, must see things clearly only at one definite distance away. Most objects must be out of focus. The lenses are very convex, hence the focal distance is short and these simple eyes must be near-sighted ones. They may serve simply to distinguish the lighter from the darker parts of the environment.

Motion and Locomotion

Muscles are composed of cells highly specialized for contractility. They are grouped together into fibers, and the fibers in turn into muscles which act as units in moving the body and its appendages (Fig. 58). The number of muscles in an insect body is very large, sometimes at least 4,000, in contrast with 400 or 500 in the body of man. The ends of the muscles which move the jaws, legs, and wings of insects are secured to the inner surface of some portion of the body wall, since there are no bones to serve for this attachment (Figs. 64 and 68).

Insect muscles agree with those of the higher animals in being mostly of the striated type, in which alternate light and dark bands cross the fibres (see Fig. 55, *C*). They differ from the muscles of the larger animals in being yellowish or colorless; and, the fibers not being enclosed in tendinous sheaths, they seem softer than those of vertebrates.

We have already indicated, however, that they are very efficient in operating the small bodies of insects. They are also capable of remarkable endurance, as indicated by the long-sustained flight of many insects, during which the wings may vibrate several thousand times a minute. This, like the rapid reproduction of insects, is dependent upon a high rate of metabolism; that is, the rapid conversion of food materials into living protoplasm and the equally rapid breaking down of the living tissues in order to release the energy necessary for all bodily activities. Most insects literally lead a fast life.

The Reproductive System of Insects

In some animals, each individual may be both male and female (as in the common earthworm); but among the insects, male and female reproductive organs are always borne by different individuals. Male and female insects are often equally injurious. In some species the females are more injurious, either because the adult males are short-lived and do not feed (as in scale insects) or because the female inflicts injury in the egg-laying act (for example, the tree crickets). Male insects are generally smaller than the females. The sexes are sometimes indis-

tinguishable on external appearance but generally show minor differences by which they can be identified. In many species of flies, the sexes can be told apart by the difference in the eyes, as shown in Fig. 50. Frequently an examination of the tip of the abdomen will show differences sufficient to distinguish the sexes. In some cases the two sexes are so different looking as to appear like widely separated kinds (*Cf.* Figs. 127 and 128).

The reproductive organs are usually found toward the tip of the abdomen (Fig. 53), although when the eggs are developing they often pack the entire body cavity of the female. The opening from the reproductive organs is near the posterior end of the body in all insects, and is commonly surrounded by external genitalia. In the female, there is an *ovipositor* (Figs. 46 and 97), an organ for thrusting eggs into the ground, the tissues of plants, or the bodies of other animals. In the male, there are *claspers* (Fig. 53), used to hold the female during mating, and the *penis.* The external genitalia are coming to be used very extensively in the determination of species, the small, and often complex, parts showing perhaps more distinct differences between species than any other group of structures.

In either sex, the *gametes* or germ cells (eggs and sperms, respectively) are developed from cells of ordinary appearance, and prepared for union in the sex glands. These glands (Fig. 57) are commonly more or less compact bodies lying among the other organs of the abdomen or suspended by filaments from the inside of the dorsal wall of the body. The *testes* and *ovaries* differ so much in form that no brief general description can be given. Each consists internally of a number of minute tubes or beadlike strings of cells, the *ovarian tubes* in the female and the *testicular follicles* in the male, down which the sex cells pass as they become more and more highly specialized and finally emerge as matured eggs and spermatozoa. As the eggs descend the ovarian tubes, the shell is secreted about them by the small cells that form the walls of the tube. From the sex glands the gametes are conveyed toward the exterior of the body through tubes known as *vasa deferentia* or *seminal ducts* in the male and *oviducts* in the female. Pending mating, the accumulated sperms are held in the body of the male in dilatations of the vasa deferentia known as *seminal vesicles.* At the time of mating, the sperms are usually received into a special pouch of the female system known as the *seminal receptacle* or *spermatheca,* which is attached to the oviducts or vagina. Later, as the eggs are being laid, some of the stored sperms are forced out upon them when they pass the opening of the seminal receptacle, thus bringing about fertilization. In the case of the honeybee queen, the sperms retain their viability in the seminal receptacle throughout her lifetime of several years. Eggs may be fertilized by these sperms years after the mating took place. The two oviducts usually unite to form a

common duct, the *vagina*, and the two seminal ducts usually fuse into a single *ejaculatory duct*. *Accessory glands* of the male secrete the fluid with which the sperms are mixed, and sometimes saclike coverings for packets of sperms known as spermatophores; and in the female they secrete a substance for cementing eggs together, or fastening them to leaves and other objects, or capsules to enclose a number of eggs. The correspondence of the organs of male and female is shown in the following table (after Folsom, compare with Fig. 57):

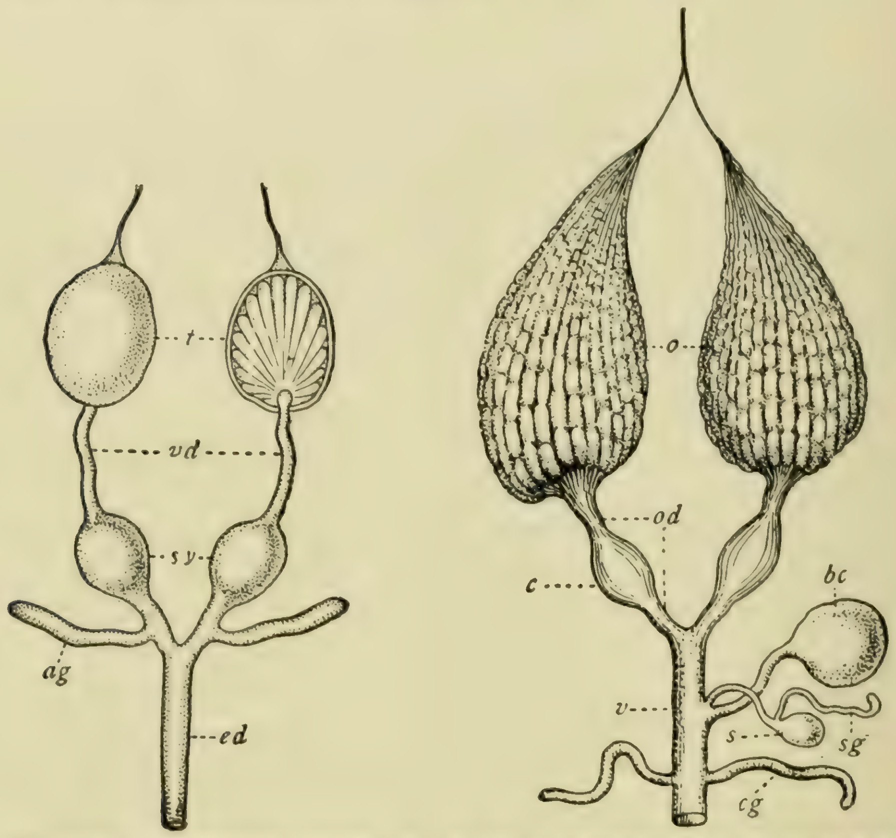

FIG. 57.—Male reproductive organs, on the left, diagrammatic; right testis is shown in section to expose the testicular follicles. *ag*, accessory glands; *ed*, ejaculatory duct; *sv*, seminal vesicles; *t*, testes; *vd*, vasa deferentia.

Female reproductive organs, on the right, diagrammatic. *o*, ovary; *od*, oviduct; *c*, egg calyx; *v*, vagina; *s*, spermatheca; *bc*, bursa copulatrix; *sg*, spermathecal gland; *cg*, colleterial gland. (*From Comstock's "Introduction to Entomology," Comstock Publishing Co.*)

Female	*Male*
Ovaries	Testes
Ovarian tubes	Testicular follicles
Oviducts	Seminal ducts or vasa deferentia
Vagina	Ejaculatory duct
Ovipositor	Penis
Seminal receptacle	Seminal vesicle
Accessory glands	Accessory glands

The growth and development of the insect following the formation and fusion of the egg and sperm is discussed in Chap. VI.

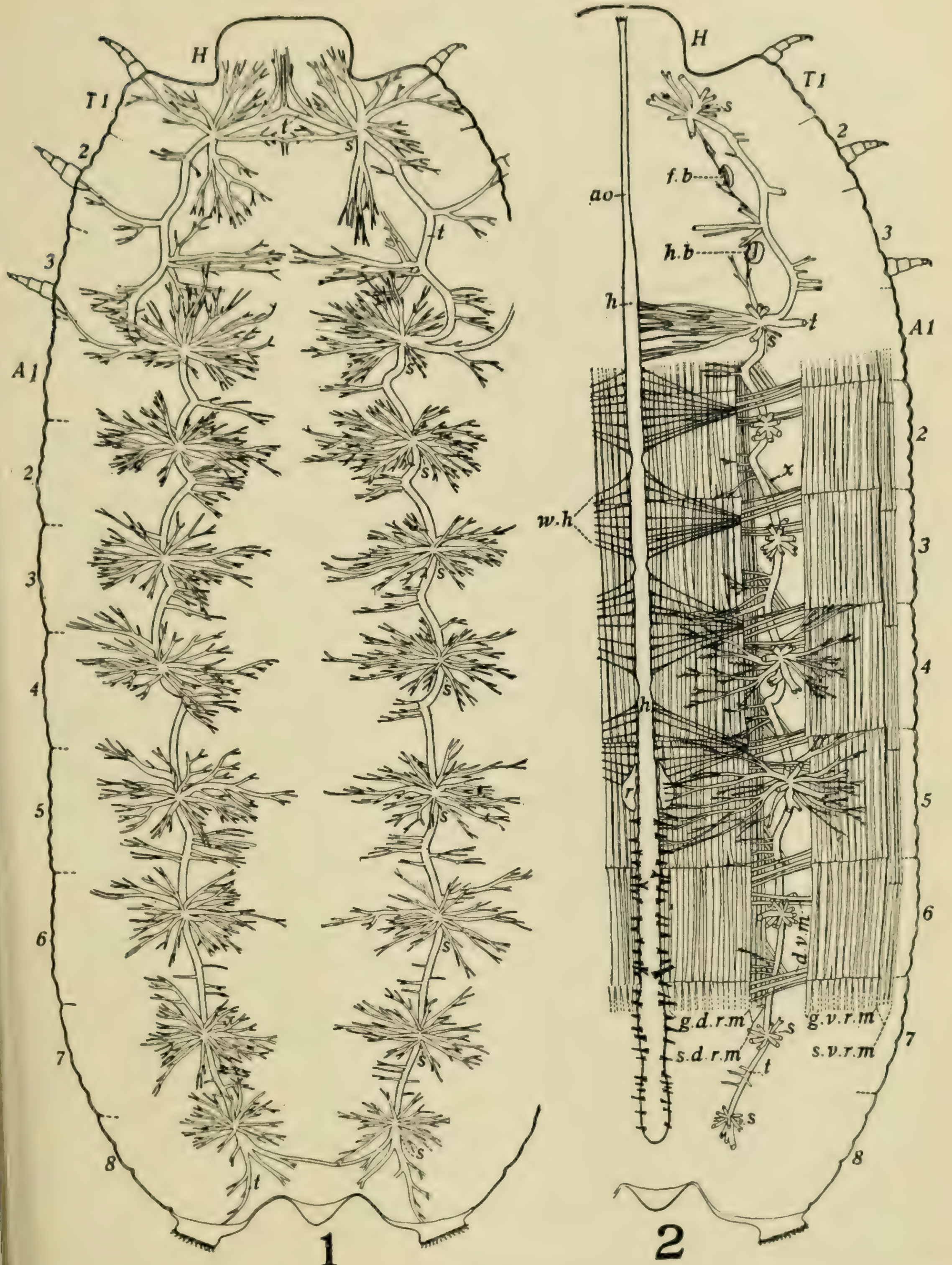

FIG. 58.—Anatomy of the tomato worm or hornworm. The body wall of the larva has been opened along the ventral side and spread to show, on the left, the principal branches of the tracheæ, all finer branches omitted; *s*, indicates the points at which spiracles open to the outside through the body wall. On the right are shown the median heart (*h*) and aorta (*ao*) with the wing-shaped muscles (*w.h.*) that hold the heart in place; the longitudinal tracheal trunk of that side (*t.t.*); the buds from which the wings of the adult are subsequently developed (*f.b.*), the front wing bud, and (*h.b.*) the hind wing bud; the reproductive organs (*r*) and some of the many muscles of the larva (*d.v.m.*, *g.d.r.m.*, *g.v.r.m.*, *s.d.r.m.*, *s.v.r.m.*, *x.*). (For the explanation of other letters see under Fig. 54.) (*From Peterson in Ann. Entom. Soc. Amer. Vol. V.*)

Protection

Protection from natural enemies and adverse climatic conditions is as necessary to safeguard the individual as reproduction is to perpetuate the species. The keen struggle for existence among animals has resulted in the perfection and adoption of a great variety of protective structures and devices, which are nowhere better illustrated than among insects.

The methods of protection among insects may be classified into:

(*a*) Protective structures and constructions;
(*b*) Protective size, form, and color;
(*c*) Protective positions;
(*d*) Protective behavior or reactions.

The importance of a chitinized exoskeleton as a protection to insects has already been emphasized in Chap. III. Such a hard body wall is characteristic of the great majority of insects. The chitin is often prolonged into bristles, spines, hairs, and scales which further protect the insect from mechanical injury, from excessive heat or evaporation, or from natural enemies, which find the hairy or spiny creatures unpalatable.

In certain caterpillars the protective value of the hairs is further increased by venom which fills them, and which nettles or poisons other animals that touch the hairs (see p. 17). The body fluids of blister beetles and some other insects are corrosive or poisonous. Many insects, especially in the bug order (Hemiptera), have odors that are repulsive. Some, like the celery caterpillar, give off odors or bitter secretions from eversible glands (Fig. 140, *b*), the sudden erection of which may have value in frightening certain enemies.

Insects build many curious constructions to protect themselves or their young. The best known of these are the cocoons of moths and butterflies, which are formed of silk secreted from the mouth. A great variety of cases or nests is used to protect especially the motionless pupa stage (see Fig. 85). Sometimes the larva stage is protected by the cocoon throughout growth, as in the case of the case-making clothes moth (Fig. 504, *b*) the bagworm (Fig. 461), and the caddice worms. Soil, leaves, small pebbles, shavings of wood, and many other substances are used to cover the body. Or a special secretion or excretion may be poured out through the body wall; as the waxy, woolly covering of mealybugs and many aphids. The social insects build elaborate nests, like the paper globe of the bald-faced hornet, the earthen mounds of ants, the soil pyramids of termites, or the overwintering nests of the brown-tail moth larvæ.

A curious method of protection is illustrated by the larvæ of the lace-winged flies and the larvæ of sweet-potato beetles; these disgusting insects pile their own excrement and shed skins on their backs for concealment.

In many flies the next to the last exuviæ of the larvæ are not shed but are retained about the body during the last larval and pupal stages, forming an excellent protective case(Fig. 85, *C*). The elevating threads that bear the eggs of the lace-winged fly (Fig. 73, *R*) illustrate another device which is probably of protective value.

It is probable that size may have protective value from certain enemies, extremely small insects being overlooked by larger enemies and unusually large insects appearing too formidable for certain of their smaller enemies. Some insects have a very grotesque appearance, which may well be frightening to some of their enemies. Concealing form and coloration (camouflaging) is pronounced among the insects. It takes two special forms. One condition, known as *protective resemblance*, is well illustrated by walking sticks (Fig. 99), which look so much like the twigs among which they live as to be difficult to detect except when they move. The other condition is known as *mimicry*. Many butterflies, flies, and other insects which are edible to birds and toads resemble in shape or color, or both, other butterflies which are poisonous or bitter to taste, or wasps which have a sting. It is believed by many naturalists that the palatable kinds gain a valuable protection from their natural enemies by this deceptive appearance. Such resemblance to another animal is known as *protective mimicry*. If the camouflaging or mimicry enables its possessor to stalk its prey or lie in ambush more successfully, it is called *aggressive resemblance* or *aggressive mimicry*. Many insects that have stings or bad tastes, so as to be distasteful to predators, are gaudily marked, like the bright-banded wasps. This is called *warning coloration*.

The positions in which an insect normally lives and feeds may make other protection less necessary. Insects which burrow in the soil, or tunnel in trunks of trees, or live in fermenting organic material, or swim through the water, or live on the skins or in the bodies of animals, gain a greater or less degree of security from extremes of temperature, excessive evaporation, and storms. They also incidentally gain security from a great many of the parasites and predators that would molest them if they fed in exposed situations.

Some insects which normally feed in exposed places have learned to take shelter or hide at the approach of certain enemies. Others depend upon their legs or wings for escape. Running away, flying away, jumping, swimming, or diving is perhaps the commonest of all protective measures. A few insects carry away their young or eggs when forced to retreat. An interesting method of escape, rather widely exemplified, is by insects feigning death or "playing 'possum" when danger threatens. Leaf beetles, click beetles, measuring worms, sphinx larvæ, cuckoo wasps, and many curculios are examples of insects that behave in this manner.

In contrast to those just mentioned are the pugnacious insects that stand their ground or take the offensive when danger threatens them or

their nests. The stinging Hymenoptera illustrate this best, although many kinds pinch or pierce with the mouth parts when handled. Others which have no weapons threaten or show fight, and doubtless succeed with their bluffing especially if they resemble well-protected kinds.

Just as some kinds enjoy a measure of immunity by living in situations removed from the beaten paths of insect life, so others, by using the less-crowded periods of the day, escape attack from some enemies though they expose themselves to others. Insects which remain quiet during the day and become active at dusk are called *crepuscular* insects; those which confine their activity to the darkness of night are called *nocturnal.*

Summary

Insects, although very different structurally from man, perform the same functions or life processes that are familiar to students of human physiology; and, although very small, their internal organization is fully as complex as that of the larger animals. The most important differences in internal anatomy and physiology, between insects and men are the following:

1. Insects have no lungs, but breathe through intricately branching tracheæ that carry air to every part of the body. They inhale and exhale, not through mouth or nostrils, but through small holes along the sides of the body known as spiracles.[1]

2. The blood has no red corpuscles and does not transmit the gases of respiration. The circulatory system is an open one; the principal vessel or "heart" lying dorsal to the alimentary canal and the blood elsewhere flowing in the body cavity without veins, arteries, or capillaries.[1]

3. The excretory organs ("kidneys") of insects, known as Malpighian tubes, open into the front part of the hind-intestine.[1] They form insoluble excretory products, rather than urine.

4. Insects have no digestive organs corresponding to the liver and pancreas of higher animals, yet they are capable of digesting a remarkable variety of substances.

5. A great variety of glands, which open to the outside of the body or into the alimentary canal, form secretions of great importance in the metabolism, economy, and ecology of the insect.

6. The central nervous system is a ladder-like or string-like chain of ganglia along the ventral side of the body, except one complex nerve center in the head (the "brain") which is dorsal to the alimentary canal.[1]

7. The organs of vision, although diverse and conspicuous, are in most cases probably not highly effective. They are totally different structurally from the eyes of other animals. Insects have widely scattered and intricate organs for hearing, sometimes on the abdomen, sometimes

[1] These characteristics should be added to those of external anatomy cited on p. 85 to distinguish insects from other animals.

on the legs, sometimes associated with the antennæ, but never as evident ears on the sides of the head. Organs of smell and taste in insects are not so localized as in man. Such diffuse chemical detectors are probably very important to the lives of insects.

8. The small and relatively unintelligent insects are aided in their persistence by a great variety of protective structures, forms and colors, positions and habits.

CHAPTER V

THE MOUTH PARTS OF INSECTS

The most important way in which insects inflict losses and injury upon man and his possessions is by eating or feeding. Since insects feed in various ways, it is evident that a knowledge of insect mouth parts is of prime importance in the study of entomology. By those interested in controlling insects, this part of insect anatomy receives very careful consideration.

The Segmentation of the Head

The head of an insect is believed to be composed of six segments, or twice the number in the thorax, although it looks like a single segment. The reasons for concluding this are that in the embryonic condition of certain insects that have been studied, six nerve ganglia and six pairs of rudimentary appendages can be recognized in the part that subsequently forms the head. Since the typical arthropod segment bears one ganglion and one pair of jointed appendages, this can only mean that six such segments have fused to from the head of the insect. At this stage of development, the mouth opening is found about midlength of the head between the third and fourth segments. Probably in the ancestors of present-day insects these six segments were as distinct as those of the abdomen in the insects living now; and each segment bore a pair of appendages, all very much alike and similar to the legs.

For the function of walking, we concluded (p. 78) that is an advantage to have the segments distinct and the appendages thereof wide spread to form two tripods. But for chewing and ingestion of food the appendages must be close together where they can work against each other, to cut off, hold, and masticate the food. So the head of the insect (Fig. 60) has come to be more and more compact, its six segments have fused together and almost all trace of their conjunctivæ has been lost. Its walls have become thick and firm to serve as an adequate base for the attachment of the powerful muscles needed to operate the mouth parts. In this way the skull case (called the *epicranium* in insects) has been developed. This strong epicranium supports the eyes, the antennæ, and the mouth parts. It encloses the brain, the mouth cavity or pharynx, and the muscles that operate the mouth parts. In insects, the size of the head is not an indication of the development of the brain, but is correlated largely with the size and strength of the jaws.

Differences in the various appendages, sutures, and sclerites of the head are much used in determining the names of insects. To one who understands these parts, they will tell almost the whole story of the insect's food habits. So it is important to learn the names of the appendages and sclerites that follow.

The Sclerites of the Head

The most evident landmarks on the wall of the head of adult insects are the large compound eyes (Figs. 50, 65, and 70), described in Chap. III. In some insects there is an impressed line or suture running over the top of the head, between the compound

eyes on the median line, and forking into two branches toward the front, the whole thing being like the letter Y, with its stem toward the thorax and its arms toward the front. This suture is called the *epicranial suture* (Fig 59). The area of the wall of the head between the branches of this suture, or the equivalent area in insects where the suture cannot be found, is known as the *front*. It usually bears the median one of the ocelli. Below the front are two other areas or sclerites typically separated from each other by transverse sutures. The upper one of these is called the *clypeus*, sometimes divided into two parts (Fig. 59), and the lower one the upper lip or *labrum* (Fig. 62). One *condyle* or root of the mandible articulates to the clypeus, while the labrum is hinged along its entire base to the clypeus but is otherwise free and movable as an upper lip. The area between the compound eyes on the upper part of the head is called the *vertex*. Here the remaining two ocelli (Figs. 50 and 60) are usually located, and from this part the antennæ (Figs. 49, 59, and 65) arise. The cheeks or sides of the head below the compound eye and between it and the mandible are called the *genæ*.

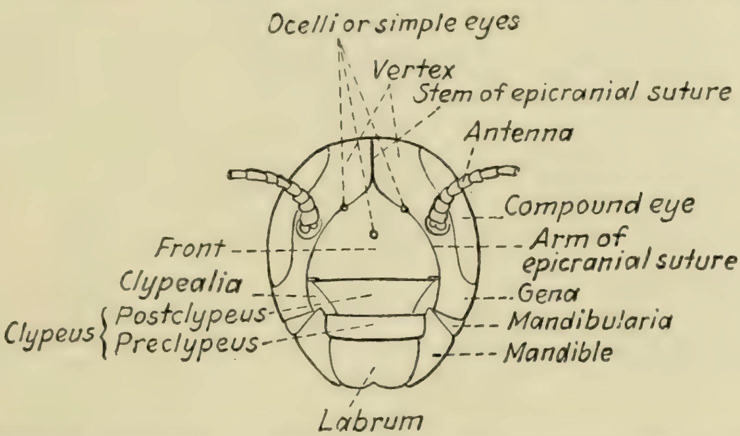

FIG. 59.—Diagram of hypothetical insect head in dorsal or front view, showing epicrania suture, sclerites and appendages. (*Redrawn from MacGillivray.*)

The part of the head that abuts against the thorax is called the *occiput* (Fig. 60) and bears a small opening in the skull case through which all the food, as it is swallowed, and also the nerve cords, dorsal blood vessel, and tracheæ, pass from head to thorax. This passageway is called the *occipital foramen* (see Fig. 67, *B*).

The compacting and fusion of the originally separated segments of the head has not been strictly in the direction of the long axis of the body, but a distorsion has carried the foremost segments, with their appendages, toward the top of the head, leaving the mouth at the very front of the body; or sometimes, by reason of an opposite tendency, the mouth has been shifted backward and comes to occupy a place at the lowermost part of the head.

The Appendages of the Head

The appendages of the first one of the head segments have become replaced by, or specialized into, the compound eyes (Figs. 50, 65 and 70). Those of the second segment are the antennæ or feelers, (Fig. 49; see p. 82). The third pair of the original appendages has been lost but we have in this region an unpaired sclerite of the head, developed somewhat like an appendage, the *labrum* or upper lip (Figs. 60 and 62). The appendages of the fourth head segment are the *mandibles*, or first pair of jaws (Figs. 60 and 62); those of the fifth segment the *maxillae*, or second pair of

jaws (Figs. 60 and 62); and those of the sixth segment the *labium* or lower lip (Figs. 60 and 62). In addition to the above parts, portions of the wall of the pharynx are sometimes projected outward, or otherwise so specialized that they form an essential part of the mouth parts; the one from the dorsal wall (roof of the mouth) is called the *epipharynx* (Figs. 62 and 65), the one from the ventral wall (floor of the mouth) is called the *hypopharynx* (Figs. 62 and 65). The typical arrangement of these parts with reference to the mouth opening may be indicated by the following diagram. It is plotted to represent the arrangement of

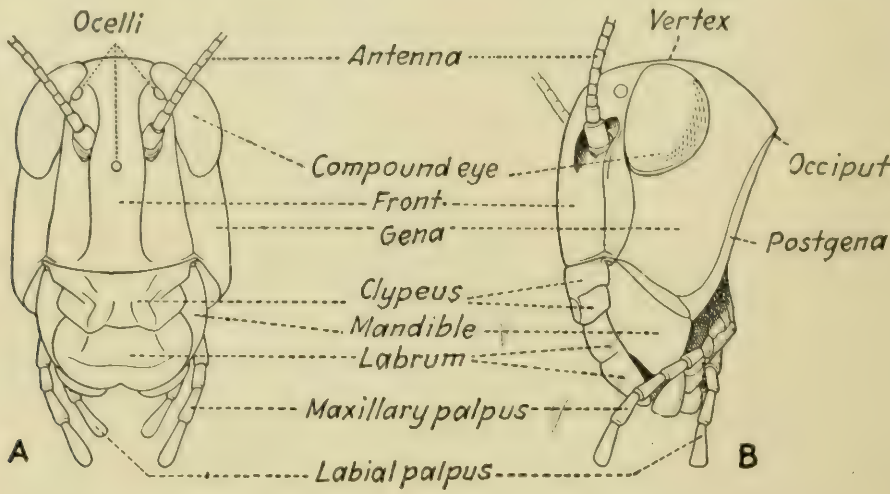

FIG. 60.—Outline of the head of a grasshopper showing sclerites and appendages. *A*, as seen from in front; *B* from the side. (*Rearranged from Folsom's "Entomology," Courtesy P. Blakiston's Son & Co.*)

parts as the insect would face the reader. The parts that are printed in italics are believed to be homologous to the legs of the thoracic segments. The parts written in parentheses constitute the mouth parts.

Right compound eye	Vertex	*Left compound eye*
Right ocellus		Left ocellus
Right antenna	Median ocellus	*Left antenna*
	Frons	
Right gena	Clypeus	Left gena
	(Labrum)	
	(Epipharynx)	
(*Right mandible*)		(*Left mandible*)
	MOUTH	
(*Right maxilla*)		(*Left maxilla*)
	(Hypopharynx)	
	(*Labium*)	

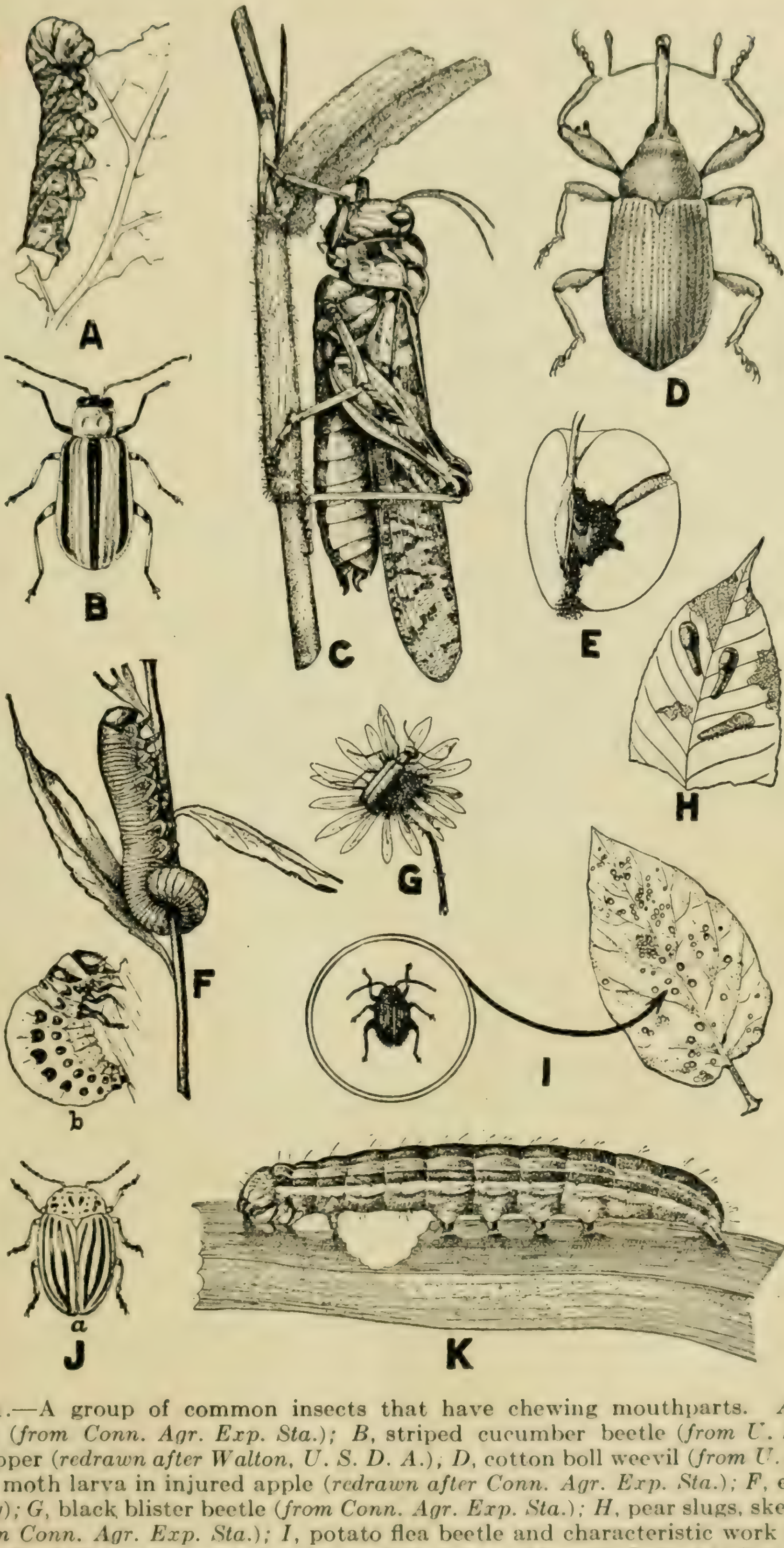

FIG. 61.—A group of common insects that have chewing mouthparts. *A*, tomato hornworm (*from Conn. Agr. Exp. Sta.*); *B*, striped cucumber beetle (*from U. S. D. A.*); *C*, grasshopper (*redrawn after Walton, U. S. D. A.*), *D*, cotton boll weevil (*from U. S. D. A.*); *E*, codling moth larva in injured apple (*redrawn after Conn. Agr. Exp. Sta.*); *F*, elm sawfly (*from Riley*); *G*, black blister beetle (*from Conn. Agr. Exp. Sta.*); *H*, pear slugs, skeletonizing a leaf (*from Conn. Agr. Exp. Sta.*); *I*, potato flea beetle and characteristic work on potato leaf (*original*); *J*, Colorado potato beetle, *a*, adult; *b*, larva (*from U. S. D. A.*); *K*, army worm feeding on leaf (*from U. S. D. A.*)

Such chewing insects are regularly controlled by spraying or dusting with a stomach poison such as arsenate of lead.

The eight parts which are collectively called the mouth parts vary extremely in different insects for different kinds of feeding. They are first described as they are found in an insect that chews solid foods, such as a grasshopper, cricket, beetle, or caterpillar. Insects of this type of mouth parts (Fig. 61) inflict losses upon American agriculture in excess of half a billion dollars a year.

The Chewing Type of Mouth Parts

1. *The Labrum* (Figs. 60 and 62).—This so-called upper lip covers the mandibles from in front, much as our upper lip covers our teeth. It helps to pull food into the mouth. There is often a notch at the middle of the labrum which is of service in holding the edge of a leaf in position so that the mandibles can bite across it effectively. Very often the insect places itself in such a position at the edge of the leaf that the sagittal plane of its body (the plane that divides the body into two equal halves) is parallel to the plane of the leaf. Some insects, however, can eat directly into the face of a leaf away from its margin.

2. *The Epipharynx* (Fig. 62).—If we had only the chewing insects to consider, it would hardly be worth while to give a separate name to this part. But in some other types of mouth parts it becomes differentiated into an important structure. In the grasshoppers and crickets, the epipharynx is inseparably attached to the labrum forming the inner or under face of the labrum; and is continuous with the roof of the mouth and thence into the œsophagus. It is a sensory area believed to contain end-organs of taste.

3. *The Mandibles* (Figs. 60 and 62).—The mandibles, teeth, or first pair of jaws, are, in chewing insects, the most important part of the mouth structures. Besides masticating the food, they are the structures that cut it off or tear it off of the leaf or other object on which the insect is feeding. In different insects they function to carry things, to fight with, or to mold wax. In the chewing insects there are generally several projections or small teeth on each mandible, which work against those of the opposite side and so make very efficient grinders. It should be noted that the action of the mandibles and maxillæ in insects is transversely, or from side to side, instead of longitudinally, or up and down, as in man.

Each mandible is typically a single, nearly solid piece of chitin, roughly shaped like a pyramid with three faces, one of which is continuous with the gena or cheek (see Fig. 60, *B*). These heavy teeth articulate to the clypeus and the genæ. Two sets of muscles operate them, one closing them against each other, the other pulling them apart.

4. *The Maxillæ* (Figs. 60 and 62).—These are the second pair of jaws, much more complicated in structure than the first pair, but working from

side to side in a manner much like the mandibles. The exact shape differs with the kind of food and the manner of feeding, but the following parts are typically represented. A central body of three or four sclerites,

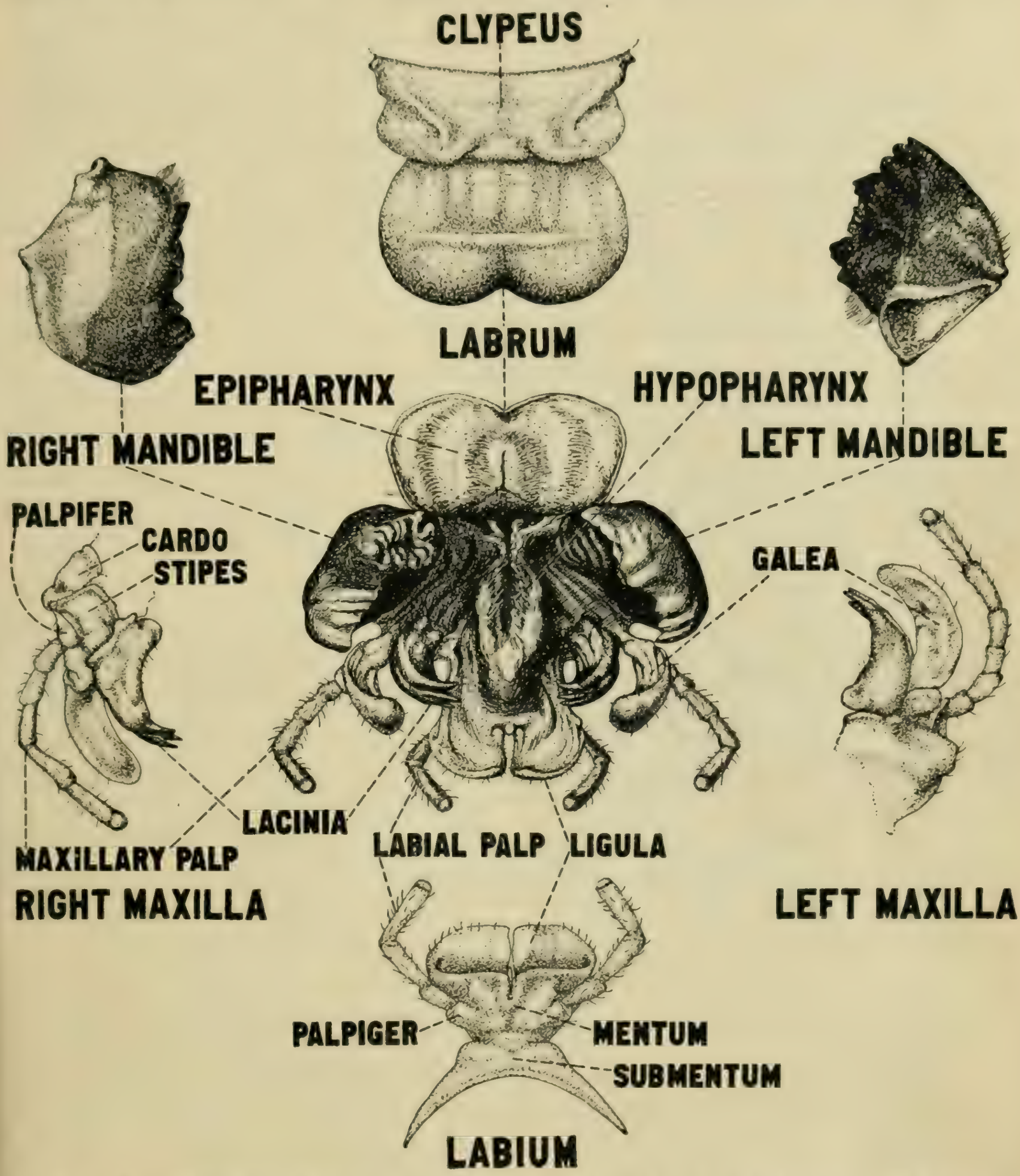

FIG. 62.—The chewing type of mouth parts as found in a grasshopper. The central figure is looking into the mouth with all the appendages widespread. The upper left shows ectal view of right mandible; upper right ental view of left mandible; upper center the labrum with the clypeus to which it attaches; lower left is ectal view of the right maxilla; lower right, ental view of left maxilla; lower center, ectal view of labium. The hypopharynx is shown near the center of the central figure. (*Original; drawings by Antonio M. Paterno.*)

(*cardo*, *stipes*, *palpifer*), from which three appendages arise. One of the appendages is antenna-like in shape, of from one to five or six segments, and is a kind of sense organ bearing tactile hairs and probably also organs

of smell or taste. It is known as the *maxillary palp* or *palpus* (Fig. 62) and is regularly the longer of the two pairs of palps found in chewing insects. The second appendage, called the *galea*, is very variable in form (helmet-like in the grasshopper); and the third, known as the *lacinia*, is the tooth part of the maxilla, modified often for cutting, grasping or grinding the food. The central body of the maxilla articulates to the lower part of the posterior wall of the head (see Fig. 60, *B*) and its several parts are freely movable by muscles that run out from inside the wall of the head.

5. *The Hypopharynx* (Fig. 62).—This is a tongue-like prolongation of the floor of the mouth opening, usually attaching to the inside wall of the labium. It is of interest as the part through which the salivary glands of insects open, these glands being especially significant in the silkworm (see p. 38) as also in some disease-carrying insects.

6. *The Labium*[1] (Figs. 60 and 62).—A good idea of the function of this part is conveyed by its common name, lower lip. It stands apposed to the upper lip, closing the mouth below or behind. It is the most complicated of all the parts, but we easily analyze its structure when we understand its origin. It has developed from two maxilla-like pieces by the two growing together along the middle line. It therefore consists of a large central body, more or less produced into lobes or appendages at its free end, and giving off at each side a short antenna-like appendage known as the *labial palp* (Fig. 62). The labial palps are regularly shorter than the maxillary palps, the number of segments varying from one to three or four. Their function is similar to that of the maxillary palps. In some insects care will be needed not to confuse the palps with antennæ, especially if the antennæ are concealed. The labium attaches to the neck of the insect between the maxillæ at the back part of the head.

How Insects Feed

Most of our serious insect pests feed in one of the following ways:

(*a*) They tear or pinch off, chew up, and swallow, bits of plant and animal tissue, much as a cow eats the leaves off a stalk of corn. In other words they are "chewers," like grasshoppers and caterpillars, and are said to have chewing mouth parts[2] (see Fig. 61).

[1] The student should notice the very similar spelling of the names for upper lip, *labrum*, and lower lip, *labium;* the latter name having an *i* where the former has an *r*—otherwise the same.

[2] In most textbooks these two general feeding habits have been called "biting" and "sucking." A little reflection will show that "biting" is a particularly ambiguous term, which in common usage conveys exactly the opposite meaning to that intended in the classification of insect mouth parts. That is, when one speaks of a *biting insect* the average person thinks—not of a beetle or a caterpillar chewing up leaves—but of a "biting" mosquito or flea or horsefly, whose mouth parts, according to the usual

(*b*) Or they extract from beneath the surface of a plant- or animal-body the body liquids (without swallowing the tissues) just as a person might insert a straw into a piece of wet sponge and suck out the liquid or into a cocoanut and suck out the "milk." In other words, they are "drinkers," like mosquitoes or aphids, and are said to have piercing-sucking mouth parts[1] (see Figs. 2 and 63).

The condition of the mouth parts in a typical chewing insect has been described in some detail because it is the most primitive type and the kind from which all other mouth parts have been derived. Insects with chewing mouth parts may generally be controlled by spraying or dusting with a stomach poison.

The Piercing-sucking Type of Mouth Parts

The piercing-sucking mouth parts take the most valuable liquids in the world—the sap of growing plants and the blood of living animals. In order to get this food they puncture or pierce the skin of the animal or the epidermis of the plant, making a very tiny, invisible hole with their mouth stylets through which they suck the sap or blood from beneath the surface. There are two very distinct operations involved in this act—(*a*) piercing and (*b*) sucking—hence we call these mouth parts piercing-sucking. The insects that have piercing-sucking mouth parts include both serious animal parasites, such as many flies, the fleas, and the blood-sucking lice, and destructive crop pests, especially the true bugs of the orders Homoptera and Hemiptera (Fig. 63). Insects of this type of mouth parts are therefore pests of importance to both the livestock raiser and the grain farmer or gardener.

The appearance of the mouth parts of this type is totally different from those described above. We do not find a complex group of appendages surrounding an evident mouth. In fact it is sometimes hard to tell just where the mouth opening is, it is so small or well hidden. We do not find hard, toothlike mandibles for grinding. What we do find (see Figs. 64, *C* and 65) is a long, needle-like beak, slender, cylindrical, usually jointed, which may point forward, downward, or backward, but, when not in use, is generally found laid back on the breast between the front legs. In many cases there are no palps at all, in other subtypes one pair, and rarely both pairs are present.

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classification, are not *biting* at all but *sucking*. Thus the "biting housefly" would have, according to such a classification "sucking" and not "biting" mouth parts. The term "sucking" is also objectionable because it is too general; as shown in the table at the end of this chapter, there are several, radically different, kinds of mouth parts which are all "sucking" or suctorial in function. We therefore urge the adoption of the term *chewing* instead of "biting" and *piercing-sucking* instead of "sucking," for the two commonest types of mouth parts.

[1] See footnote on p. 114.

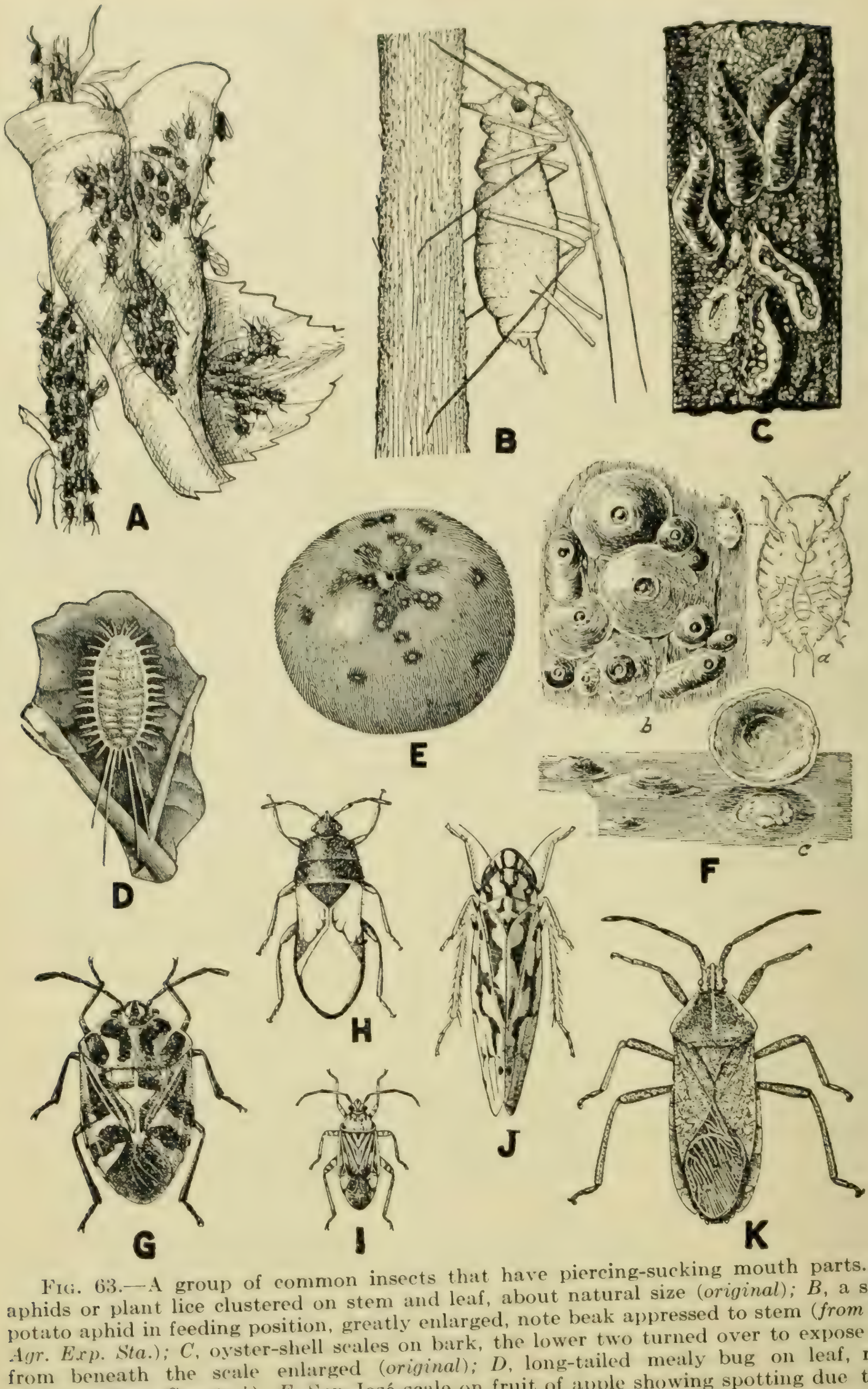

Fig. 63.—A group of common insects that have piercing-sucking mouth parts. *A*, aphids or plant lice clustered on stem and leaf, about natural size (*original*); *B*, a single potato aphid in feeding position, greatly enlarged, note beak appressed to stem (*from Ohio Agr. Exp. Sta.*); *C*, oyster-shell scales on bark, the lower two turned over to expose eggs from beneath the scale enlarged (*original*); *D*, long-tailed mealy bug on leaf, much enlarged (*from Comstock*); *E*, San José scale on fruit of apple showing spotting due to its feeding (*from Fulton*); *F*, San José scale, *a*, first instar nymph, or "crawler," greatly enlarged; *b*, a group of scales as seen on the bark, much enlarged; the large round ones cover mature females, the elongate ones cover males, and the small ones cover the second instar nymphs;

In the true bugs, such as chinch bugs, bedbugs, aphids, and squash bugs, we find a jointed slender beak of three or four segments (Fig. 64, *C*), inside of which lie four extremely slender, pointed stylets (Figs. 64, *B*, *C*), that normally cling together to form what appears like a single, slender, brown bristle. The jointed beak is not a closed cylinder but is open down the entire front side and at the end, like a bit of gutter trough. This largest, outside piece is the *labium* (Fig. 64, *C*). *It has nothing to do with puncturing the plant or sucking up the sap.* Lying inside the groove of the labium are four very sharp, chitinous "stabbers" or "needles," the *stylets*, which do the work of piercing the plant and drawing out the sap. These four pieces are the two *mandibles* and the two *maxillæ* (Fig. 64), all extremely modified from their condition in chewing insects. The *labrum* in this type (Fig. 64, *B*, *C*) is a short flap that covers the groove in the labium toward the base of the latter.

Sometimes the mandibles and maxillæ have little sharp barbs near the apex. As the stylets are alternately thrust out from the head and pulled back at a rapid rate, the barbs catch in the leaf tissue or flesh and help to sink the stylets deeper into the wound at each thrust, until the level of sap or blood is reached. Each maxilla is doubly grooved from end to end along its inner face (Fig. 64, *A*), and these concave faces of the two maxillæ fit tightly together to make two closed tubes known as the *food channel*, and the *salivary duct*. A mandible fits closely against each side of the apposed maxillæ and a tongue (*Tn*), on the outer face of each maxilla locks into a groove (*Gr*) on the inner face of each mandible so that they can slide in and out on each other. In this way the delicate hollow apparatus is greatly strengthened for the thrust into the tissues.

When the stylets have reached the sap beneath the epidermis of leaf or bark, or the blood, in blood-sucking forms, it is sucked up through the microscopic tube called the food channel (Fig. 64, *A*) by expansion of the walls of the pharynx inside the head (Fig. 64, *B*). The labium shortens up or bends back out of the way and does not enter the plant tissues or flesh. There may be sensory hairs at the end of the labium that serve to sample the food and select the spot for feeding, and this part may also be used as a kind of fulcrum to steady the head and the stylets while they are piercing. However, its chief function appears to be to act as a kind of scabbard for the four-part dagger that we call the stylets.

Any insect having mouth parts of this nature is open to suspicion as a serious enemy of crops or animals. If leaves show minute pale or brown

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c, a group of scales from the side, one of them lifted to show the body of the female insect (*from Quaintance, U. S. D. A.*); *G*, harlequin cabbage bug, enlarged (*from U. S. D. A.*); *H*, chinch bug, enlarged (*from S. Dak. Agr. Exp. Sta.*); *I*, tarnished plant bug, enlarged (*from U. S. D. A.*); *J*, grape leafhopper, enlarged (*from U. S. D. A.*); *K*, squash bug, enlarged (*from Iowa Agr. Exp. Sta.*).

Such piercing-sucking insects cannot be controlled by spraying or dusting with stomach poisons; but many of them can be destroyed by applying contact insecticides to their bodies.

spots, or are curled or wilted (see Fig. 2, p. 6), this kind of an insect should be sought as the probable cause. Many piercing insects feed on

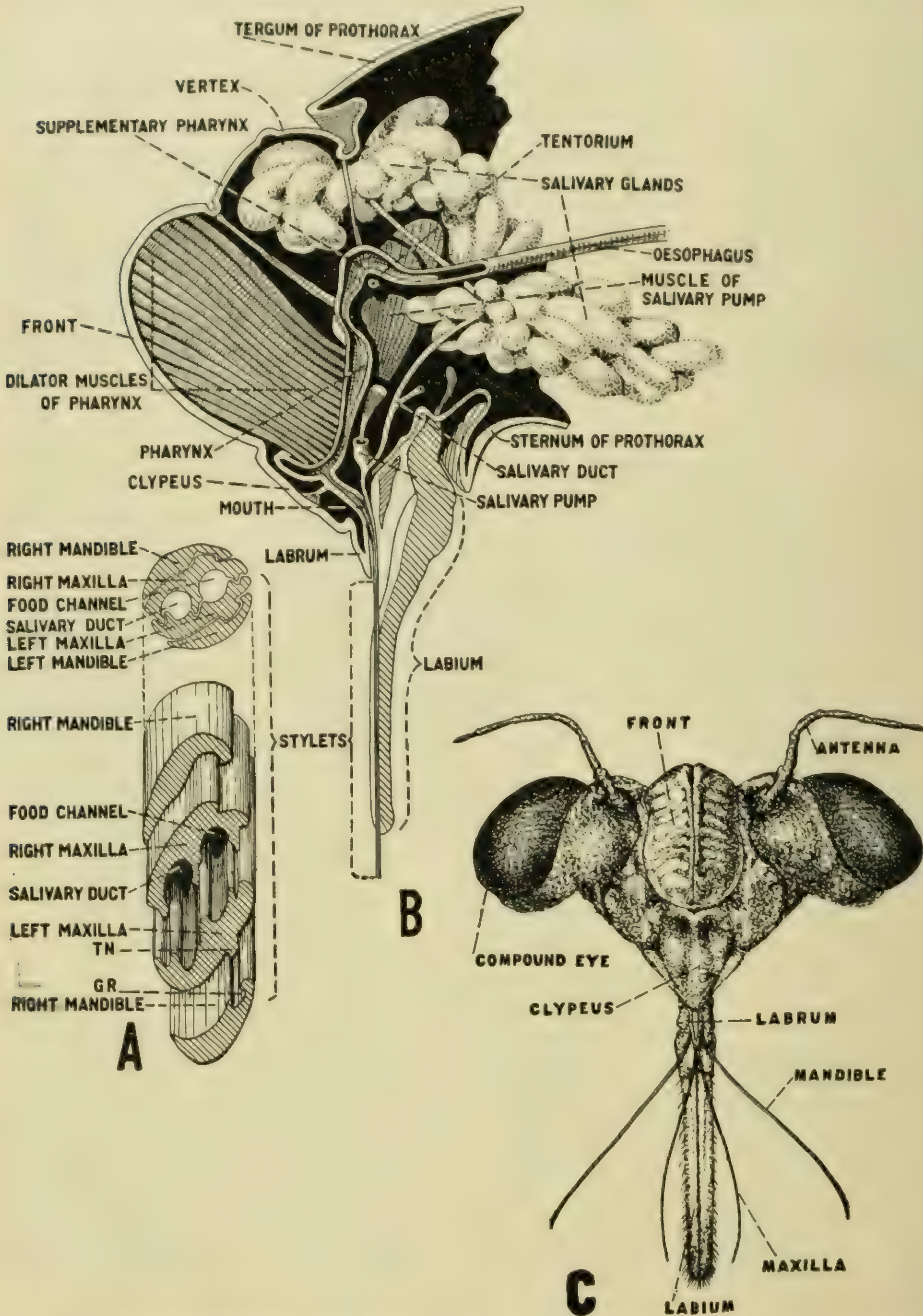

FIG. 64.—The piercing-sucking type of mouth parts as found in the squash bug and cicada. *A*, cross-section and isometric projection of the stylets as described by Tower, greatly magnified (*original*); *B*, sagittal section of the head of the periodical cicada showing the relation of the stylets to the mouth opening, the sucking pharynx, the salivary glands, duct and pump, etc., much enlarged (*redrawn after Snodgrass, Proc. Entom. Soc. Wash.*); *C*, front or dorsal view of head and mouth parts of a dog-day cicada, much enlarged (*original*).

other insects in a manner helpful to us, but as a group they are predominately destructive.

One important principle should be fixed in mind at this point. *No insect with piercing-sucking mouth parts can be killed by applying a stomach poison, like arsenate of lead or Paris green to the plant on which it is feeding.*

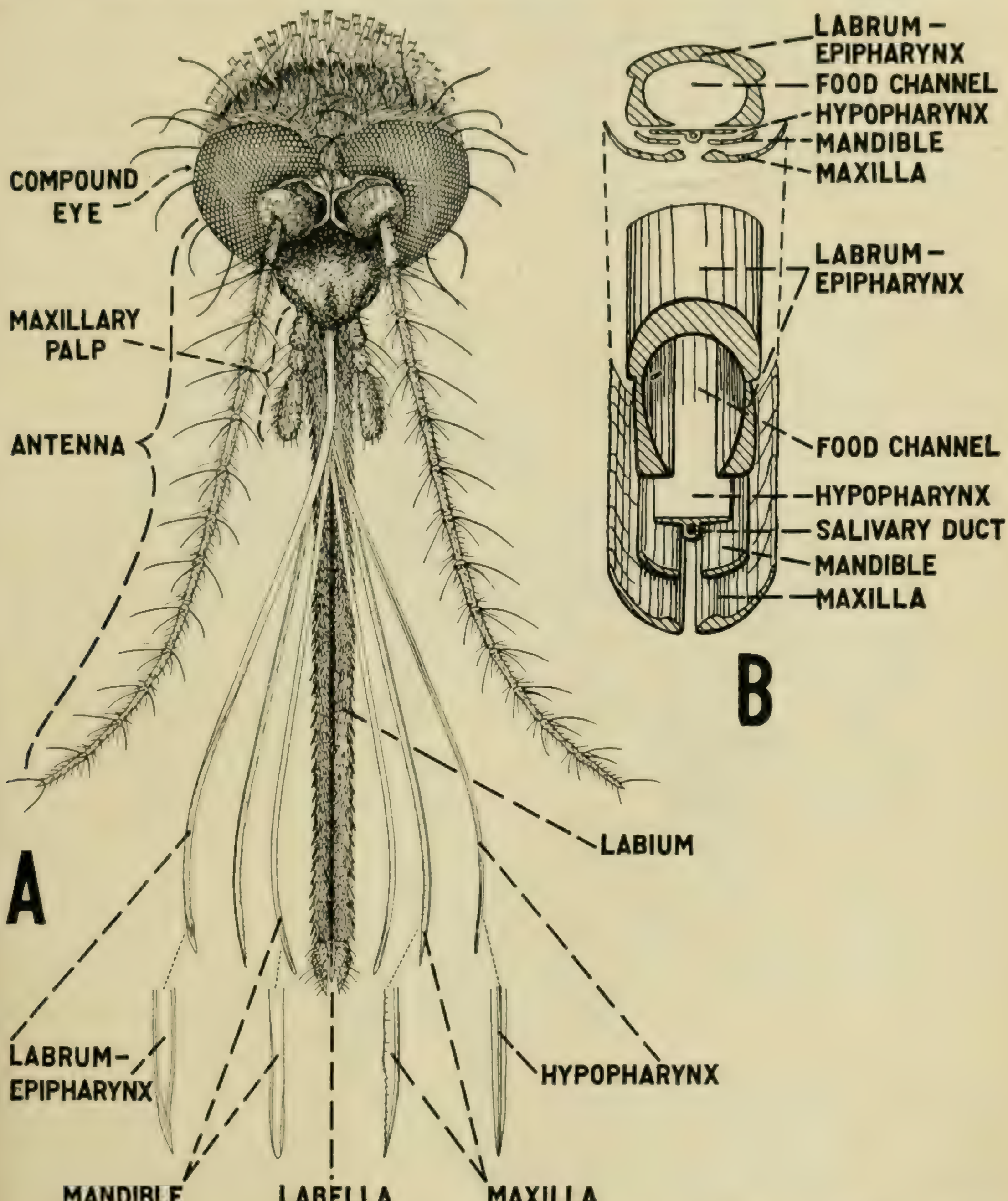

Fig. 65.—Piercing-sucking mouth parts as found in a female mosquito; common biting-fly subtype. *A*, front or dorsal view of head and mouth parts with the stylets spread out of the labium and their tips more enlarged below. *B*, cross-section and isometric projection of the stylets as described by Howard, Dyar, and Knab. Much enlarged. (*Original; drawing by Antonio M. Paterno.*)

These insects cannot take up solid particles as food, and the minute stylets may penetrate through a coating of arsenate of lead on leaf or fruit and get none of it; since they do not suck up anything off of the outer

surface. The only way we could kill piercing-sucking insects with a stomach poison as they are feeding on plants would be to poison the sap of the plant. Experiments have been tried along that line, but so far there is no material known that can be inserted into the trunk of the tree and plugged up, that will kill the insects feeding on leaves and twigs, without injuring the tree.

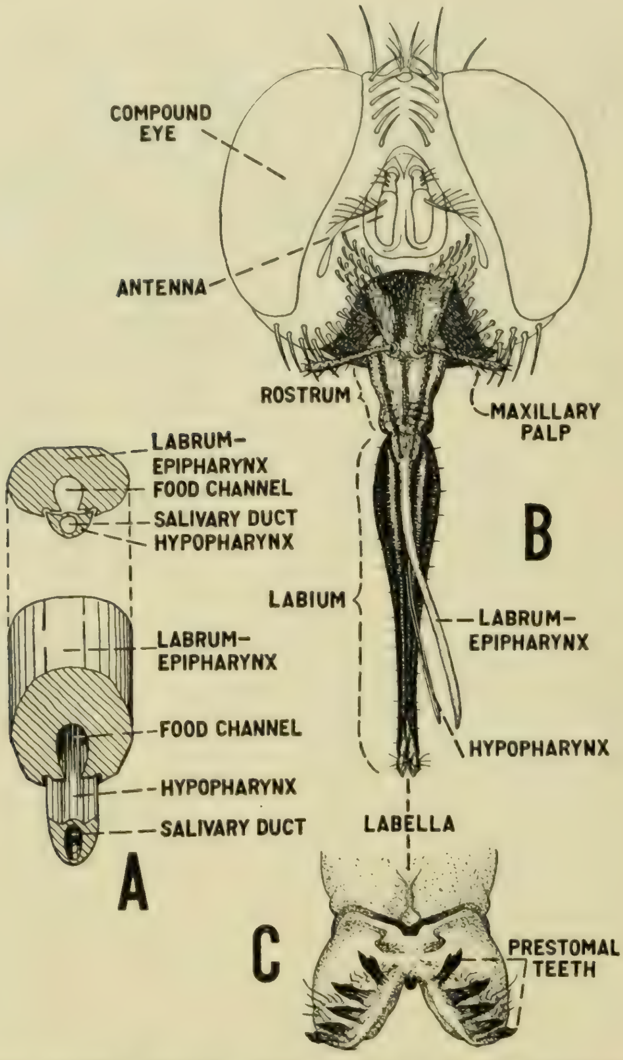

FIG. 66.—Piercing-sucking mouth parts as found in the stable fly; special biting-fly subtype. *A*, cross-section and isometric projection of the stylets to show the food channel and salivary duct. *B*, front or dorsal view of the head and mouth parts with the stylets spread out from the labium. *C*, the labella more magnified to show the prestomal teeth, which are cutting organs, according to Patton and Cragg. Much enlarged. (*Original; drawings by Antonio M. Paterno.*)

Varieties of Piercing-sucking Mouth Parts

Besides the piercing-sucking mouth parts of the true bugs, there are several variations of the same functional type, especially among the blood-sucking insects. These are spoken of as subtypes and their chief structural features are indicated in the table of mouth parts below. For example, in the piercing apparatus of the mosquito (Fig. 65), we note that there are six stylets instead of four, the *labrum-epipharynx* and the *hypopharynx* being long and slender like the *mandibles* and the

maxillæ. We find also a pair of palps (entirely wanting in the bugs), which are the *maxillary palps.* The food channel (Fig. 65, *B*) is formed chiefly by the labrum-epipharynx, which is the heaviest of the six stylets. The groove along its lower or posterior face is closed by the hypopharynx. The hypopharynx carries throughout its entire length, in the *salivary duct,* the saliva that causes the irritation when a mosquito bites and the malarial organism from an infected mosquito to the blood stream of man. The labium is not jointed except for the differentiation of a pair of oral lobes or labella (Fig. 65) at its tip.

Among the flies of the house-fly family are some species, such as the stable fly, that bite, although the house fly never does. These have mouth parts of the type illustrated (special biting-fly subtype), in Fig. 66. The *labium,* the *labella,* the *labrum-*

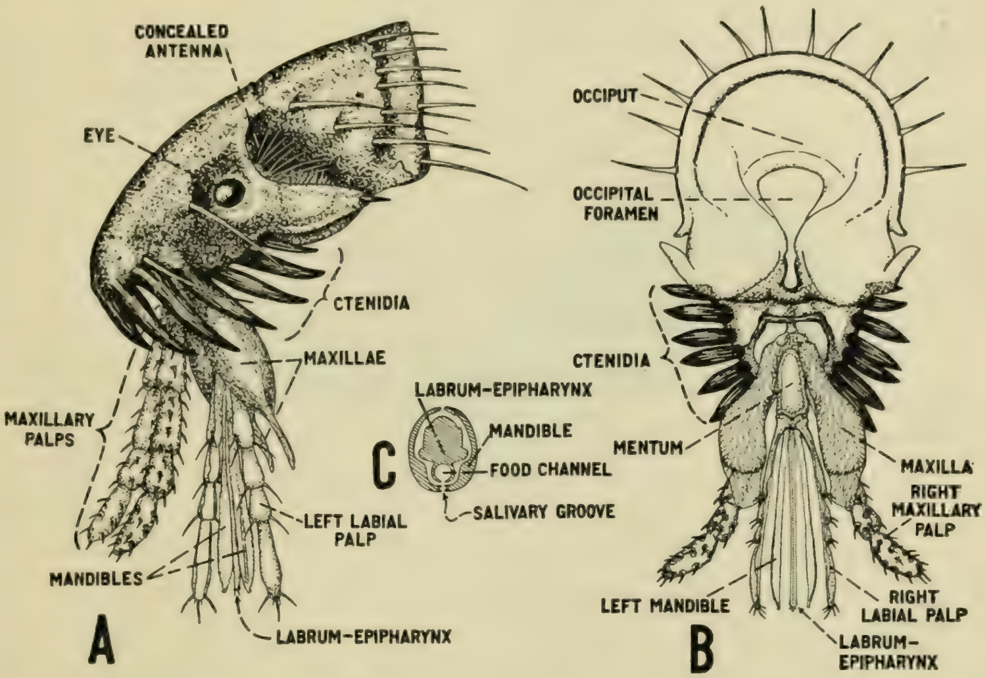

FIG. 67.—Piercing-sucking mouth parts as found in a flea. *A*, head and mouthparts in side view. Note the antenna nearly concealed in a groove in the side of the head, the small eye, the ctenidia or comb of heavy spines, and the way the labial palps shield the stylets. *B*, caudal view of head and mouth parts of a flea, the head having been removed from the thorax. *C*, cross-section of mandibles and labrum-epipharynx, as described by Patton and Cragg, to show how the food channel and salivary groove are formed. All much enlarged. (*Original; drawings by Antonio M. Paterno.*)

epipharynx, the *hypopharynx,* and the *maxillary palps* are much like those of the mosquito. But the mandibles and maxillæ are entirely wanting, there being therefore only two stylets. Patton and Cragg[1] state that piercing by these insects is accomplished by the rapid protraction and retraction of the labella, which bear sharp teeth on their inner faces (Fig. 66, *C*); and that the labium as well as the stylets follows these teeth into the flesh. The food channel is formed by the labrum-epipharynx and hypopharynx and the salivary duct traverses the hypopharynx (Fig. 66 *A*).

The mouth parts of the fleas show another variation in the combination of stylets that are used for piercing and sucking (Fig. 67). There are three stylets: the *labrum-epipharynx* and the two *mandibles.* The mandibles have toothed edges and are the chief cutting organs. The labrum-epipharynx is grooved on its ventral or posterior face, much as in the stable fly (Fig. 67, *C*; compare Fig. 66, *A*). In order to make this

[1] PATTON and CRAGG, "*A Textbook of Medical Entomology,*" Christian Literature Society for India, London, 1913.

groove or food channel tight enough to suck up blood, the slit is probably closed by the apposition of the edges of the mandibles. Each mandible has in its posterior edge a tiny groove (Fig. 67, *C*); these two grooves when pressed together, form a second tube, the *salivary groove*, to carry the saliva to the tips of the stylets. The maxillæ do not enter the wound, but are broad flaps, said to serve as levers or fulcra to steady the head during the piercing and sucking operations. They have a pair of prominent *maxillary palps*. The labium suggests somewhat the condition in chewing insects, consisting of a basal piece called the *mentum* and two, slender, jointed pieces called the *labial palps*. These palps are concave on their sides which are next to the stylets, and the two together form a protective sheathe for the mandibles and labrum-epipharynx.

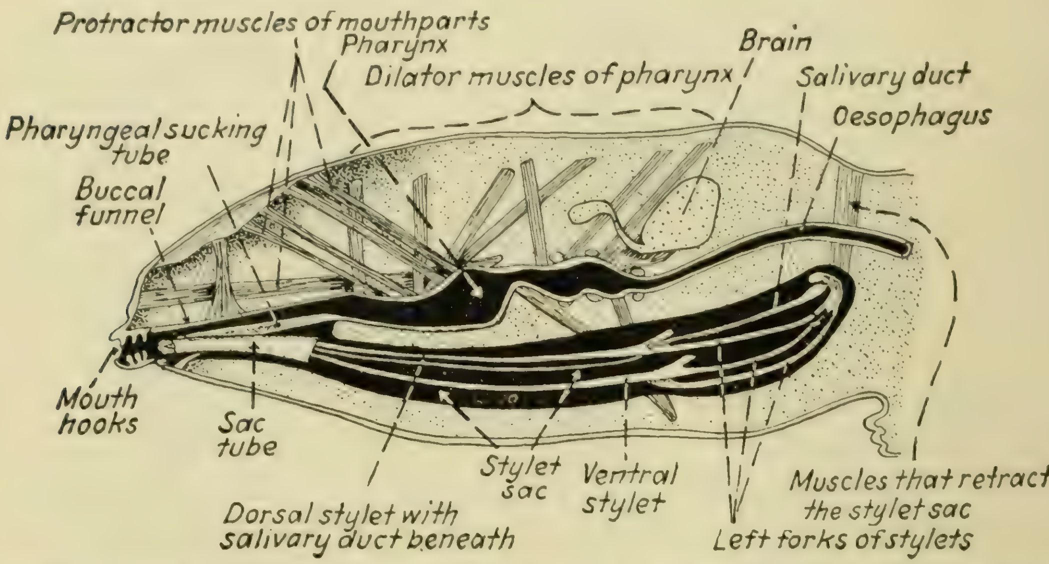

FIG. 68.—Piercing-sucking mouth parts as found in the human body louse. Note the stylet sac lying beneath the pharynx in which are two prominent stylets. In order to feed, the stylets are thrust through the mouth opening and forced into the flesh and the blood as drawn is sucked up through the pharyngeal sucking tube. (*Redrawn after Imms and Peacock.*)

The piercing-sucking organs of the blood-sucking lice are anomalous and the homologies of the parts are not clear. According to Tillyard,[1] mandibles, maxillæ, and both pairs of palps are wanting. There is no external evidence of the mouth parts except a few teeth around the mouth opening (Fig. 68). When not in use, the piercing structures are entirely withdrawn into a sac, the *stylet sac*, that branches off from the pharynx near the front of the head and ends blindly beneath the œsophagus near the back of the head. At the caudal end of this sac are attached two slender stylets (*dorsal* and *ventral stylets*) that extend nearly to the mouth opening and terminate inside a *sac tube*. These are said to be developed from the hypopharynx. Each stylet forks at its caudal end, and the salivary duct is closely associated with the dorsal stylet. When the louse is ready to feed, the protractor muscles force the stylets out of the mouth and into the flesh. As the blood exudes, it is drawn up through the pharyngeal sucking tube and into the pharynx by the action of the dilator muscles of the pharynx. The saliva possibly serves to prevent coagulation of the blood.[2]

[1] TILLYARD, "Insects of Australia and New Zealand," Angus & Robertson, Ltd., Sydney, 1926.

[2] See PEACOCK, "*Parasitology*," Vol. 2, pp. 98–117, November, 1918.

A Table of Insect Mouth Parts

While the chewing and piercing types of mouth parts are the commonest and most important, there are a number of other types found in insects, as indicated in the following table, which is a summary of this chapter.

A. **The Chewing Type** (Fig. 62).—Generalized mouth parts (consisting of eight named parts surrounding an evident mouth opening), the essential features of which are two pairs of tooth-like jaws, the mandibles

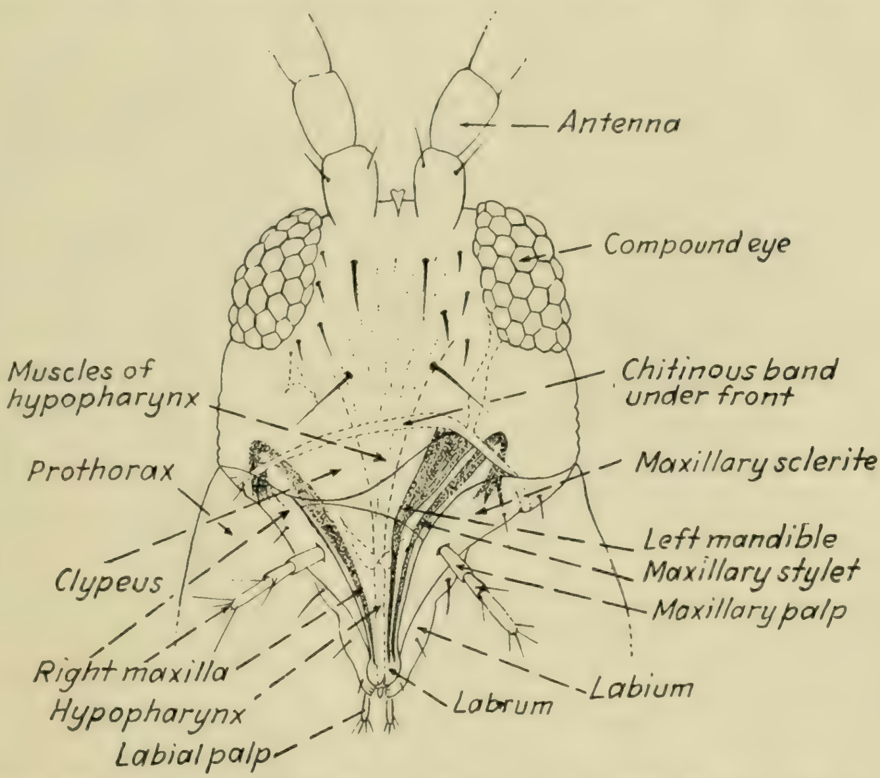

Fig. 69.—Rasping-sucking type of mouth parts as found in flower thrips. View of the head from in front with only the bases of the antennæ shown. The chitinous band serves to connect the mouth parts to the front. It also sends a branch to the left eye while the one to the right eye is a triangular rudiment. Note the two pairs of palps, the three or four stylets, and the cone formed by labrum, maxillæ and labium for sucking up the sap. (*Redrawn after Borden, Jour. Econ. Entom., June,* 1915.)

and maxillæ, fitted to work transversely (and used for tearing off and masticating food, or for carrying things, for fighting, etc.), and an upper and a lower lip. A further characteristic is the presence of *two pairs of jointed palps*.

This is the commonest type of mouth parts; found in the silverfish, grasshoppers, crickets, earwigs, termites, book lice, chewing lice, beetles, weevils, some Hymenoptera, and many insect larvæ, especially grubs and caterpillars, besides many others of little importance to man.

B. **The Rasping-sucking Type** (Fig. 69).—Mouth parts which are somewhat intermediate in structure between the piercing-sucking type

and the chewing type, but are rasping and sucking in their action, serving to lacerate the epidermis of plants and suck up the exuding sap. The right mandible is reduced, making the head and the mouth parts somewhat asymmetrical. The left mandible, the maxillæ, and, according to Borden,[1] the hypopharynx, are elongate, suggesting the stylets of the piercing type and adapted to move in and out through a circular opening at the apex of the cone-shaped head. The stylets apparently do not form a food channel nor enter deeply into the wound; and the sap as it exudes on the surface is sucked up by the cone-shaped mouth rather than by the stylets. Both pairs of palps are present. Found in the thrips.

C. **The Piercing-sucking Type.**—Specialized mouth parts characterized by a tubular, usually jointed, beak, enclosing several needle-like stylets. The outer tube is formed by the *labium*, which is simply a protective structure for the other parts and has nothing to do with piercing the tissues or drawing up the liquid food. The mandibles and maxillæ, sometimes supplemented by or replaced by the labrum-epipharynx and hypopharynx, are greatly elongated and slender structures, which serve for piercing the skin of an animal or the epidermis of a plant, and also as the food channel, *i.e.*, an inner tube up which the liquid blood or sap is drawn.

There are several structural variations of this type, of which the following must be noted:

I. *The Bug or Hemipterous Subtype* (Fig. 64).—No palps. Four stylets, two *mandibles* and two *maxillæ*, the latter partly fused. Food channel and salivary duct formed by the maxillæ. Examples: chinch bug, aphids, scale insects and bedbug.

II. *The Louse or Anoplurous Subtype* (Fig. 68).—No palps. Two prominent "stabbers" or stylets, and some associated structures. The proper names and homologies are not well understood, but, according to Tillyard, *l.c.*, the stylets are outgrowths of the hypopharynx. This type differs from all other insect mouth parts in that, when not in use, all the parts are entirely withdrawn into a long, slender pocket in the head beneath the pharynx. Examples: human lice or "cooties," hog lice, and other blood-sucking lice.

III. *The Common Biting-fly or Dipterous Subtype* (Fig. 65).—Maxillary palps present. Six stylets; two *mandibles*, two *maxillæ*, the *labrum-epipharynx* and the *hypopharynx*, the last two parts forming the food channel, and the hypopharynx surrounding the salivary duct. Examples: mosquitoes, horseflies, black flies, and "no-see-ums."

IV. *The Special Biting-fly or Muscid Subtype* (Fig. 66).—So far as structure is concerned, derived, according to Patton and Cragg, *l.c.*, from the sponging type (see below) by the reduction in size of the labella and the attenuation and chitinization of the labium, which in this subtype is rigid and not retractile. The labella are provided with cutting teeth and this type differs functionally from all other piercing insects in that the *labium*, itself, enters the puncture (Patton and Cragg). The *labrum-epipharynx* and *hypopharynx* are similar to those of the

[1] *Jour. of Econ. Entomol.*, Vol. 8, p. 354, June, 1915.

sponging type, together forming the food channel; the mandibles are wanting and the maxillæ represented only by a pair of palps. This type is exemplified by the blood-sucking species of the order *Diptera*, family *Muscidæ*, such as the stable fly, horn fly, and tsetse fly.

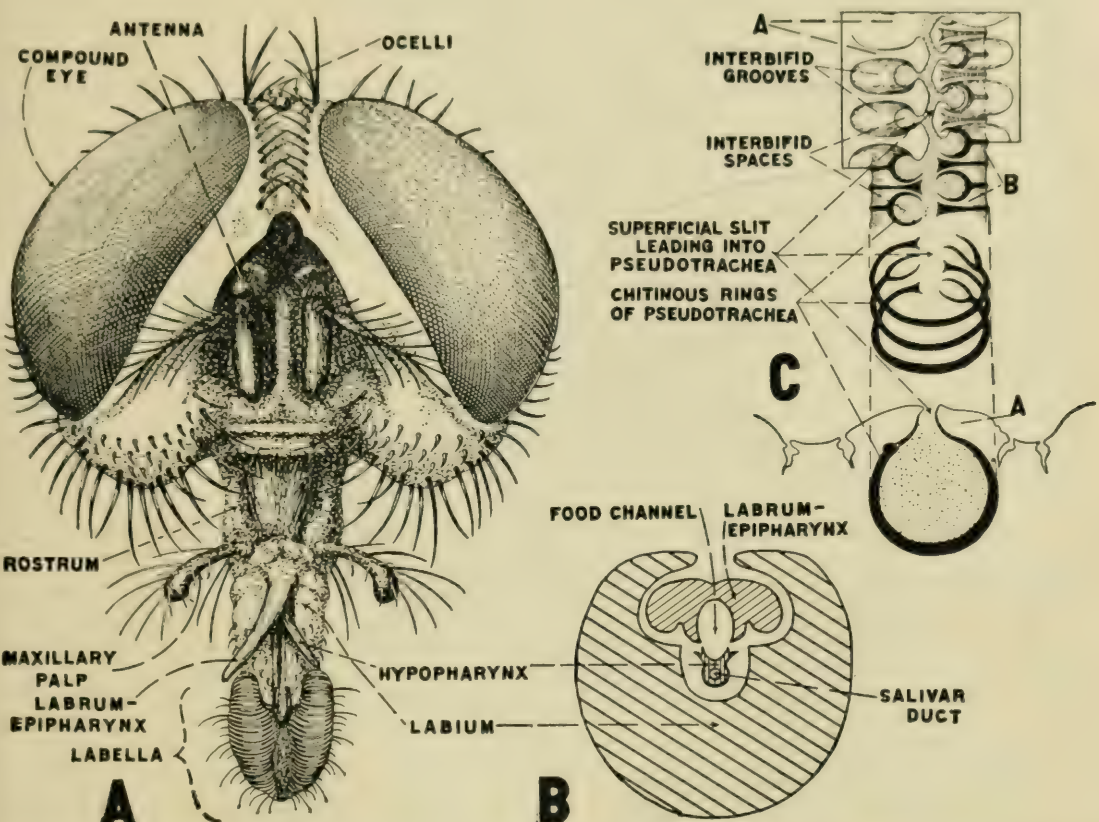

Fig. 70.—Sponging mouth parts as found in the house fly. *A*, dorsal or front view of head and mouth parts with the proboscis extended and the stylets spread out from the labial gutter. Note the pseudotracheæ and sensory hairs on the labella. Much enlarged (*original drawing by Antonio M. Paterno*). *B*, diagrammatic cross-section of the proboscis to show composition of food channel, salivary duct, and labial gutter. *C*, details of a single pseudotrachea, greatly magnified. In the upper part of the figure a surface view of the pseudotrachea shows the superficial slit and interbifid spaces through which liquid foods enter the pseudotrachea, and on the left two interbifid grooves leading to the interbifid spaces. On the right the chitinous rings are shown as seen by transmitted light. At *B* the integument of the oral surface of the labellum has been removed to expose the membrane that lines the interior of a pseudotrachea and stretches between the chitinous rings with their alternate bifid and flattened extremities. *A* is the integument of the oral surface of the labellum; *B* is the membrane lining the interior of the tube. At the center are represented three consecutive chitinous rings to show how their bifid and flattened extremities alternate on each side of the superficial slit. In the lowest part of the figure is represented a transverse section of a part of the oral surface of the labellum, cutting across a single pseudotrachea. Greatly magnified. (*B and C redrawn after Graham-Smith and Hewitt.*)

V. *The Flea or Siphonapterous Subtype* (Fig. 67).—Maxillary palps present. Only three stylets (two *mandibles* and the *labrum-epipharynx*) enter the wound. The maxillæ are triangular plates that serve as levers while biting. The labium bears two, segmented parts, which are probably the *labial palps*. This type of mouth parts is found in the fleas.

D. **The Sponging Type** (Fig. 70).—This type of mouth parts is well illustrated by the condition in the common house fly. We find on the lower side of the head a fleshy, elbowed and retractile proboscis, which is the *labium*. The end of the labium is specialized into a large spongelike organ, the *labella* (Fig. 70, *A*). The labella are traversed by a series of furrows or channels, narrowly open all along the exposed edge, the *pseudotracheæ* (Fig. 70, *C*). These insects feed on exposed liquids, such as nectar or sap; or by dissolving solid substances, such as sugar, in their saliva. When the labella are appressed to such liquids, the pseudotracheæ fill with the liquid by capillary attraction. These little channels all converge at one point on the labella and from this point the liquid food is drawn up through the food channel into the œsophagus. The food channel is formed by the labrum-epipharynx and the hypopharynx as in other flies (Fig. 70, *B*). These are the only two stylets present and in this type they are entirely incapable of piercing the skin. The mandibles are wanting and the maxillæ are represented by only a pair of maxillary palps.

This type is found in the house fly and other non-blood-sucking Muscidæ, in the Syrphidæ, and in many other of the Diptera.

E. **The Siphoning Type** (Fig. 71).—This is a very much specialized type, in which the labrum and mandibles are usually entirely wanting. The labium is represented only by the labial palps. The essential working parts are formed by the *maxillæ*, parts of which, the *galeæ*, are greatly elongated and joined to form a slender hollow tube which is coiled up under the head like a watch spring when not in use. This proboscis is not capable of piercing the skin of an animal or the epidermis of a leaf or fruit, except in rare instances. Feeding is accomplished by uncoiling this tube and projecting the tip of it into some exposed liquid (commonly the nectar in the nectary of a flower) and then sucking the liquid up through the *food channel* (Fig. 71, *B*), which runs full length through the proboscis.

This type of mouth parts is found in practically all adult moths and butterflies, the order *Lepidoptera*.

F. **The Chewing-lapping Type** (Fig. 72).—This type, which is so well illustrated by the honeybee or bumblebees, is a kind of combination type in which the labrum and mandibles are of the same structure as in the chewing type, but the maxillæ and the labium are elongated, forming a sort of lapping tongue (Fig. 72, *Gls*). Both pairs of palps are present, the *labial palps* long and conspicuous (LbPlp), but the *maxillary palps* very small (MxPlp). According to Snodgrass, a temporary *food channel* is formed by the concave inner surfaces of the galeæ, roofing over the *glossæ* and fitting snugly lengthwise against the labial palps, which in turn lie tightly against the sides of the glossæ. Through such a complexly formed tube ("held, like a straw in one's mouth, by the mandibles

grasping the bases of the galeæ while the epipharynx plugs the gap where the ends of the galeæ diverge toward the head") a drop of honey may be sucked up.

According to George E. King, in securing nectar from the open nectaries of flowers, the bee thrusts out the glossæ or tongue and licks

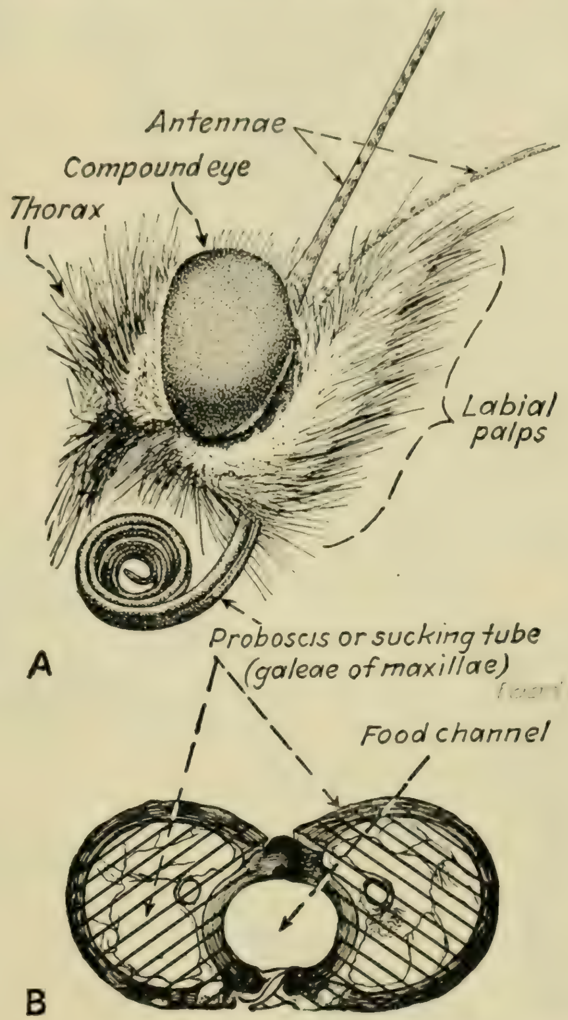

FIG. 71.—Siphoning type of mouth parts as found in a moth or butterfly. *A*, side view of the head with the proboscis partly coiled. Note the labial palps which are so covered with hairs that the segmentation cannot be distinguished. *B*, cross-section of the proboscis to show how the right and left galeæ lock together to form the food channel. Highly magnified. (*Redrawn after Comstock.*)

the nectar with the tip of it. The glossæ, thus smeared with nectar, are retracted between the labial palps and galeæ, and the nectar is squeezed off the tongue by the galeæ and deposited so as to accumulate in the small cavity formed by the paraglossæ at the base of the glossæ. Then by the bending of the labium upward near midlength the base of the glossæ is brought into close apposition to the mouth opening and the accumulated nectar passes into the pharynx. The nectar thus gathered serves as food for the bees and the surplus is stored as honey.

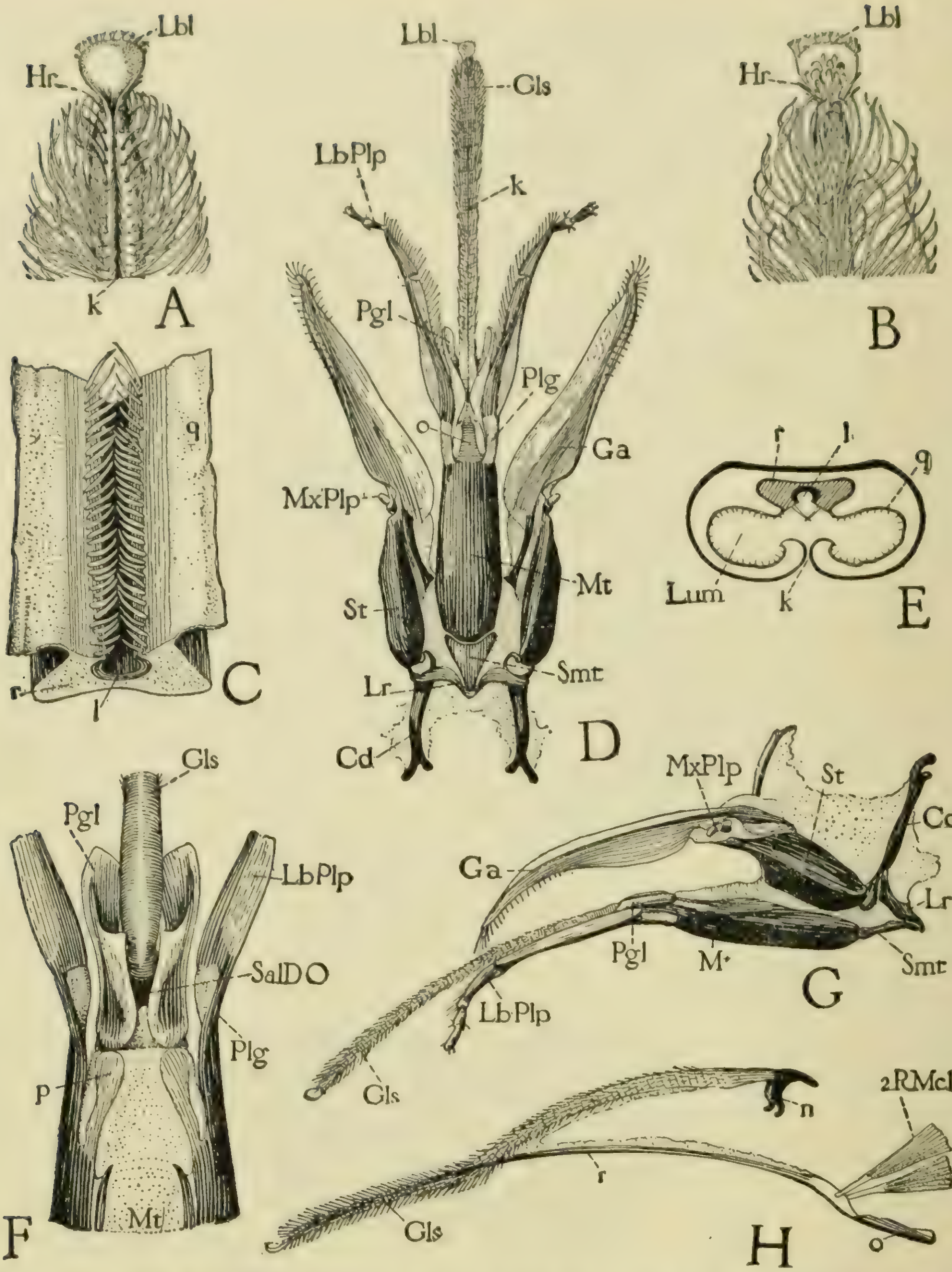

Fig. 72.—Chewing-lapping type of mouth parts as found in the honeybee. *A*, tip of tongue (glossæ of labium), under or posterior view, showing labellum (*Lbl*), ventral groove (*K*) and guard hairs (*Hr*). Greatly magnified. *B*, the same from above or anterior view. *C*, a section of the glossal rod from inside the tongue (compare *E*), still more magnified to show the inner channel (*l*) guarded by rows of hairs; part of glossal walls and long hairs of tongue omitted. *D*, the entire maxillæ and labium in ventral or posterior view. The following are parts of the maxillæ: *Cd*, cardo; *Ga*, galea; *MxPlp*, right maxillary palp; *St*, stipes. The following are parts of the labium: *k*, ventral groove in glossæ, *Gls; Lbl*, labellum; *LbPlp*, labial palps; *Lr*, lorum; *Mt*, mentum; *Pgl*, paraglossa; *Plg*, palpiger; *Smt*, submentum. *E*, cross-section of the tongue (glossæ) showing the inner channel (*l*) of the glossal rod (*r*) and the ventral channel (*Lum*) which communicates with the outside through the ventral groove. *F* distal end of mentum (*Mt*), dorsal side, with bases of palps (*LbPlp*) and glossa (*Gls*) showing opening of salivary duct (*SalDO*) at root of glossa, and paraglossæ (*Pgl*) embracing the base of the latter. *G*, lateral view of proboscis, showing parts on left side somewhat separated. *H*, lateral view of glossa with glossal rod (*r*) torn from its base, showing flexible attachment of rod to small plate (*o*) at end of ventral surface of mentum (*D*, *o*), and insertion of retractor muscles (*2RMcl*) on base of rod. *n*, basal hooks of glossa. (*From Snodgrass, Anatomy of the Honeybee.*)

The inner channel (*l*) or the ventral channel (*Lum*) of the glossæ, or both, may serve as a salivary groove to conduct saliva to the tip of the tongue, where it may be used to dissolve solids such as sugar, preparatory to swallowing. The mandibles are used for carrying things, and in the honeybee for molding wax into cells.

This type of mouth parts is found in some species only, of the order Hymenoptera, which includes the bees, wasps, and ants.

CHAPTER VI

DEVELOPMENT AND METAMORPHOSIS

That "truth is stranger than fiction" is well illustrated by the life cycles of insects. No one could possibly predict the life cycle of even the most humdrum bug with half of its manifold interrelations.

Where can one find a human biography as romantic as that of the "seventeen-year locust" or periodical cicada? Thrust as eggs into the splintered bark of an orchard tree or forest tree (Fig. 5, *A*), these insects, immediately upon hatching from the egg, drop from a dizzy height to the ground. There they burrow deep into the soil beneath the tree, construct a cave about some bit of root and enter upon the lives of hermits, withdrawn from the air and sunshine in which their lives began, and completely isolated from others of their kind. In this condition (Fig. 77, *J*) they live and grow for nearly seventeen years, and then again, as though to make up for their long period of self-denial, Comstock says, they

" . . . crawl up to the surface of the ground, like renegade monks; and, leaving their nymphlike skins clinging to the tree trunks like cast-off garments of penance, they come forth, broad-headed, broad-bodied, clear-winged creatures, (Fig. 346) well fitted to get all the experience possible out of a world whose frivolities they have so long scorned. But, like other creatures, they find a life of dissipation very exhausting, and after a few weeks they sing their last song, lay their eggs, and pass away."

By the life history or life cycle of an insect we mean the record of all that the insect habitually does and all the changes in form that it undergoes from the beginning of its life until its death, including the situations where each life stage and every season is spent and the length of time occupied by each stage.

Where Insects Come From, How They Grow and Develop and Provide for Succeeding Generations

Insects, like all other animals, begin life from a single cell known as the egg (Fig. 73). They do not appear spontaneously, or spring up out of nothing, as people sometimes suppose, but come from eggs previously hidden about us by insects of the same kind. Only occasionally do swarms of insects invade a locality from some distant point. It is probably safe to say that nine-tenths of the insect troubles of a given

farm come from eggs laid on that farm. Each farmer, or certainly each community, raises its own insect pests, with very few exceptions. It is part of the function of entomology to teach us to recognize insect outbreaks in their incipiency, and the stages of pests which are harmless, as well as those that do damage.

Before development can begin, it is usually necessary that the insect egg be fertilized by union with a sperm from the male insect (see p. 101). But many cases have been found among insects in which fertilization is not necessary, the female insect producing living, normal young without the necessity of mating. In other cases, a part of the eggs develop normally without being fertilized. This is known as *parthenogenesis*. In the honeybee the fertilized eggs generally produce "workers" or "queens" (that is, females), the unfertilized eggs invariably producing males or "drones." In aphids, all summer generations are exclusively females developed from unfertilized eggs, males appearing only in the fall and fertilizing only the overwintering eggs. In a considerable number of species, no males have been found, or in certain generations no males are produced. For example, 98 successive generations of aphids have been produced under observation without a single fertilization. Other things being equal, a parthenogenetic species is likely to be a worse pest than one in which mating is necessary; because the hazard of not finding a mate is removed and successful reproduction is that much more sure. In spite of these exceptions, the normal thing among insects is for fertilization to occur.

Eggs and sperms are living cells highly specialized for the particular function of generating complete new individuals, just as nerve cells are highly specialized for sensation and conduction, or muscle cells for contractility. In order that we may understand the specialization that these particular cells undergo, and their subsequent history, we should examine the essential parts of the insect egg and sperm.

The Egg.—The eggs of insects (Fig. 73) are not as varied in size, shape and appearance as the insects that lay them. They are very small; the characters by which they may be distinguished are often most obscure and elusive; and very little time has yet been given by entomologists to the study of insect eggs. Nevertheless, it is often possible to tell from an examination of the egg the exact kind of insect that will develop from it. This may at times be of the greatest importance in forecasting the appearance of the destructive stages of a particular insect pest.

In attempting to recognize the kind of insect from its eggs, one should note the size, shape, and color of the egg; the place in which it is found; the way in which it is laid or attached—whether on its end (Fig. 73, *S*), or its side (*K*), or on an elevating stem (*R*); or, if inserted into the tissues of plants or animals, the kind of scar made by the laying (Fig. 5); whether laid singly or in indefinite masses or in accurately spaced or definitely

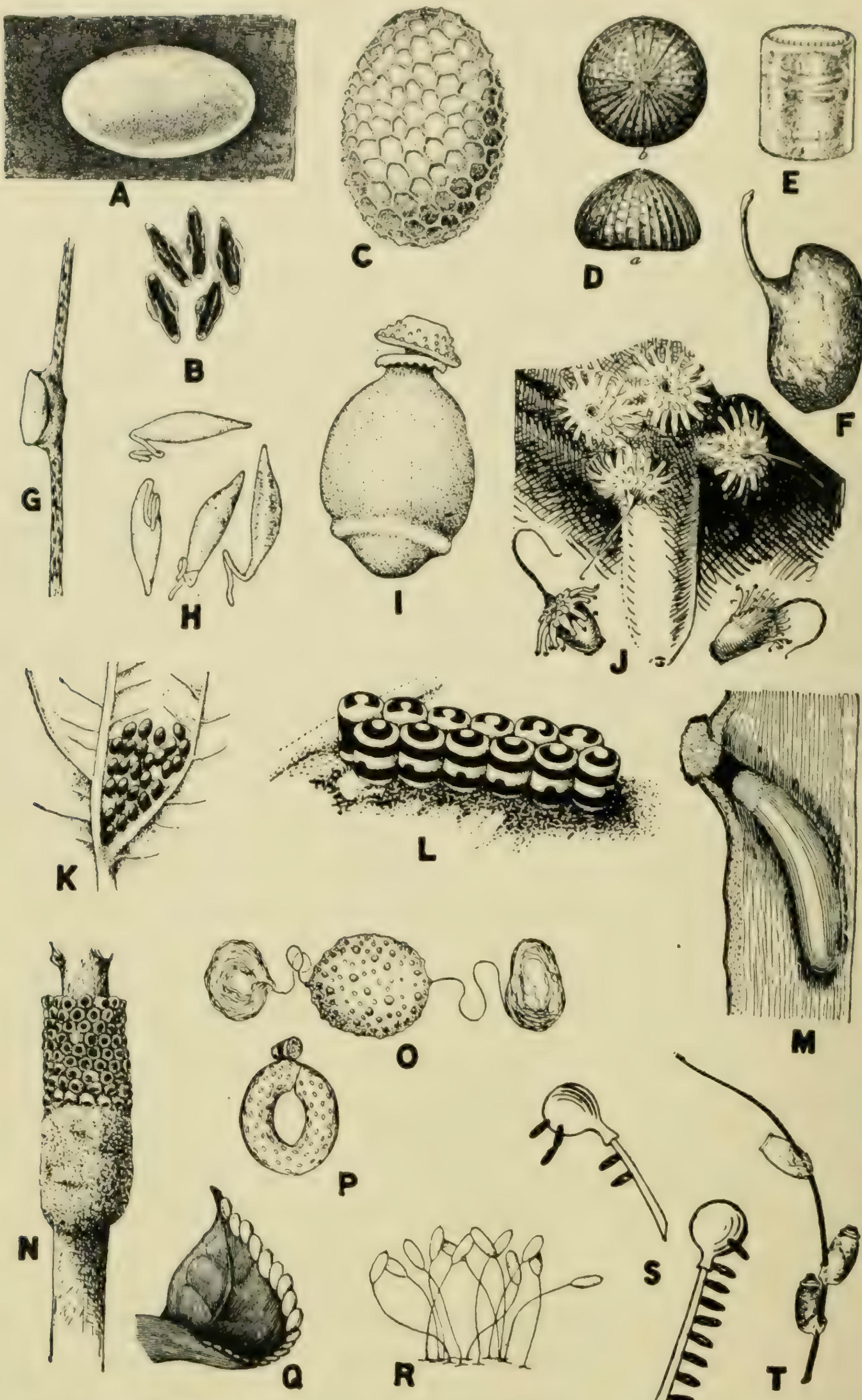

FIG. 73.—Eggs of various insects to show something of the variety in shape, pattern, sculpturing and arrangement. All much enlarged. *A*, egg of Japanese beetle; *B*, a group of eggs of the malarial mosquito; *C*, egg of Honeysuckle miner, *Lithocolletes fragi ella* (*from Crosby and Leonard*); *D*, egg of the fall army worm; *a*, side view, *b*, from above; *E*, egg of southern green plant bug, side view; *F*, egg case of great water scavenger beetle which encloses 50 to 100 eggs (*redrawn after Kellogg*); *G*, egg of a ground beetle, *Chlænius tricolor*, in its mud cell on the stem of a sedge (*redrawn after King in Ann. Entom. Soc. Amer.*); *H*, eggs of the apple seed chalcid; *I*, egg of a stone fly, *Perla immarginata* (*from Smith in Ann. Entom. Soc. Amer.*); *J*, eggs of poultry lice (*from Ohio Agr. Exp. Sta.*); *K*,

ranked groups (Fig 73, *L*, *N*, *Q*); and the arrangement of the eggs with respect to each other, whether free or cemented together, or covered over with hairs or a cement-like secretion. Of especial usefulness is the sculpturing of the eggshell as seen under a microscope. A great variety of impressions, elevations, or depressions are found, the exact shape and arrangement of which will often serve to distinguish one species from another. (Fig. 73, *C*, *D*, *E*, *H*, *I*, *J*, *O*.)

Parts of the Insect Egg.—Regardless of shape or size, the following parts of the egg will usually all be represented (Fig. 74):

(*a*) The *chorion* or eggshell, a tough protective covering.

(*b*) The *micropyle*, a small opening through the chorion usually at one end of the egg, through which the sperm may enter the egg to fertilize it.

(*c*) The *vitelline membrane*, a delicate membrane completely lining the shell within, and enclosing the following parts:

(*d*) The *cytoplasm*, or general living substance of the egg, the clear, watery, "cell sap."

(*e*) The *yolk*, or lifeless food material, which is not usually assembled into one mass as in birds' eggs, but is scattered throughout the cytoplasm.

(*f*) Finally, and most significant of all, the *nucleus*, a highly organized dynamic part of the cell, containing, besides other significant parts, the *chromatin*, which at certain regular times forms into the minute bodies known as *chromosomes*. The chromosomes (perhaps in conjunction with other portions of the germ cells in which they are borne) are the bearers of hereditary characters, which in some unknown manner determine that the insect developing from an egg laid by a bumblebee, for example, shall be a bumblebee and not a grasshopper nor a house fly: in general, a creature like its parents, with the peculiar, fundamental, structural characters of the species to which it belongs.

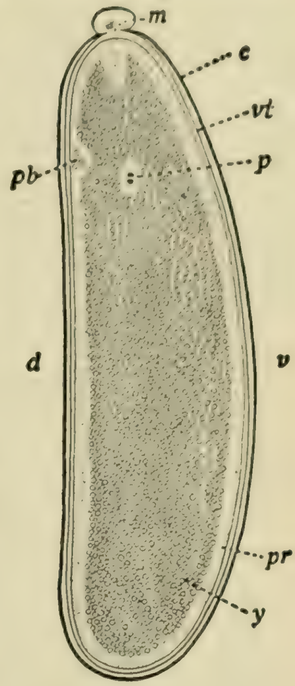

FIG. 74.—Sagittal section of an egg of the house fly in process of being fertilized. *c*, chorion; *d*, dorsal side; *m*, micropyle, with exudation; *p*, nuclei from sperm and egg about to unite; *pb*, polar bodies; *pr*, peripheral protoplasm; *v*, ventral side; *vt*, vitelline membrane; *y*, yolk. Greatly magnified. (*From Folsom's "Entomology," after Henking and Blochmann, courtesy P. Blakiston's Son & Co.*)

egg mass of the squash bug (*original*); *L*, egg mass of the harlequin bug; *M*, egg of snowy tree cricket (*from Parrott and Fulton*); *N*, eggs of tent caterpillar forming a collar about a twig. In the upper portion of the mass the eggs have not been covered with the glue-like secretion (*original*); *O*, egg of a May-fly, *Heptagenia interpunctata*, showing skein of thread at each end which anchors egg on surface of water by winding about sticks or plants (*from Morgan in Ann. Entom. Soc. Amer.*); *P*, egg mass of a caddice-fly, *Phryganea interrupta* (*from Lloyd*); *Q*, egg mass of angular-winged katydid on edge of leaf (*from Comstock*); *R*, eggs of a lace-winged fly (*original*); *S*, eggs of asparagus beetle; *T*, eggs of little red louse on hair of cow (*A*, *B*, *D*, *E*, *H*, *L*, *S* and *T* from *U. S. D. A.*).

The Sperm.—The sperms of insects are in a general way similar to those of other animals. They are elongate, extremely slender cells, with a whiplike, vibratile tail, by which they may swim actively to find an egg. When examined at high magnifications, three different parts may be distinguished (Fig. 75): (*a*) a slender, rod-like *head* which contains the nucleus and carries the chromosomes, and is believed to be the part that bears the hereditary characters of the male parent to the egg; (*b*) a *middle piece* which is thought to contain an "attraction-sphere," of significance in the division and development of the egg after fertilization; and (*c*) the *tail*. Such a curious cell is developed from an ordinary-appearing cell in the testis, during the process known as maturation.

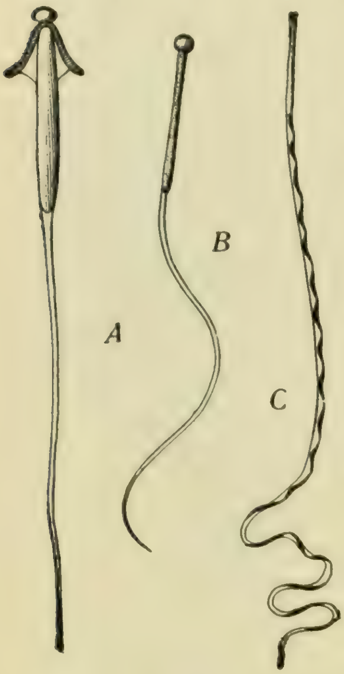

FIG. 75.—Sperms of insects. *A*, of grasshopper; *B*, of cockroach; *C*, of a scarabæid beetle, greatly magnified. (*From Folsom's "Entomology," after Bütschli and Ballowitz, courtesy P. Blakiston's Son & Co.*)

Maturation and Fertilization.—The nucleus of the egg and of the sperm is the portion that contains "the germ of life." Every other part of the egg is subservient to the nucleus, serving to protect or nourish this vital part. Before fertilization, the nucleus of the egg and that of the sperm each undergoes certain complicated changes known as *maturation*, during which a part of their substance, especially chromatin, is cast aside. In the maturation of the sperm cell, most of the cytoplasm is discarded and the cell specialized for locomotion; in the development of the egg cell most of the cytoplasm is retained and the cell specialized, by the inclusion of yolk, to nourish the embryo. In both cases only half of the chromatin substance of a normal body cell is retained.

At fertilization the sperm burrows into the egg cell (through the *micropyle*), at least the head and middle piece entering its substance to perform essential functions in the construction of the *fusion nucleus*, from which the entire new insect develops. It is the fusion of these two "half-cells," the maturated sperm from the male and the maturated egg from the female, that constitutes *fertilization*. All cells of the new body are direct descendants of the "perfect cell" so formed.

Development.—The life cycle *begins* with fertilization, the fusion of the sperm and egg into a single cell. The life cycle *ends* with a body composed of millions of cells, highly organized into a complex, living machine. All that takes place between the fertilization of the egg and the perfection of the full-grown insect we call *development* and *growth*. It is sharply divided into two phases by the act of hatching or escape from

the eggshell. That part of the development that occurs before hatching, or birth, is called the *embryology* (embryonic development) and all that takes place after hatching or birth is *post-embryonic development.*

The embryology of insects is a subject too technical to attempt to cover here, though one of fascinating interest. We would simply emphasize that life begins as a single cell, the fertilized egg, in which cannot be recognized any of the features of the creature into which it later develops. This cell, under the influence of a force we do not understand, divides, and the succeeding cells divide and further multiply and differentiate. As the cells increase in numbers, all take their place in an orderly and definite manner to form the various tissues and organs of the future insect; until when it hatches we have within the eggshell (Fig. 77, *A*, *F*, *K*) an organism capable of discharging all the necessary functions of life. During this time the egg is quiescent. The insect does not feed externally or move during the egg stage. In the egg stage, therefore, insects are never injurious and never beneficial.

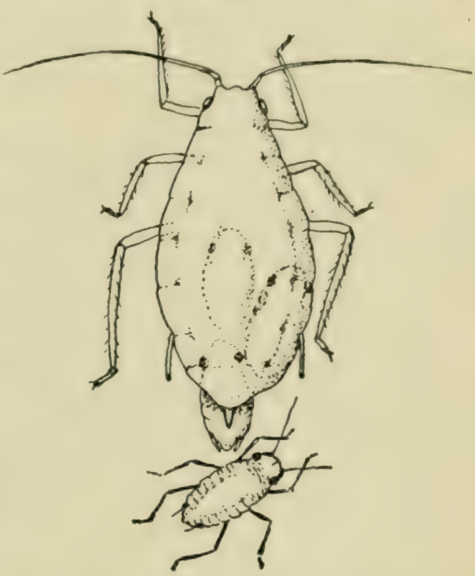

Fig. 76.—A wingless parthenogenetic green bug, giving birth to living young, ovoviviparously. (*Drawn from photographs by Hunter and Glenn, University of Kansas.*)

Types of Reproduction.—The development within the egg requires food. This may be derived from food material, *yolk, stored inside the shell* by the parent insect before the egg is laid. The parent then nourishes it no further. This method of reproduction is known as *oviparous* (*i.e.*, bringing forth eggs). It is parallelled by the condition in birds, although it should be noted that insect eggs do not require incubation or other attention from the parents after they are laid.

In contrast with this is the condition in mammals where the young, during embryonic development, establish a definite connection (the *placenta*), with the blood system of the mother and receive their nourishment, moment by moment, from the circulatory system of the parent. Food as well as oxygen for an embryonic mammal passes from mother to young by diffusion or osmosis through the so-called fœtal membranes. This condition is known as *viviparous* reproduction (*i.e.*, bringing forth active young).

A somewhat intermediate condition is found among insects, some of which do not lay the eggs but retain them until after they have hatched and then bring forth active young (Fig. 76). This is not at all equivalent to viviparous reproduction, however, because the young insect receives

its nourishment from the yolk of the egg and not from the parent's circulation. No organic connection is established. It is simply premature hatching or delayed oviposition. It is distinguished as *ovoviviparous reproduction.* The two kinds of reproduction common among insects are oviparous and ovoviviparous. A condition somewhat analogous to that found in man and other mammals (viviparous reproduction) is known only in the case of a few flies (the sheep tick, see p. 803 and the tsetse flies) in which the young are actually nourished by special nutritive glands in the uterus of the parent fly.

Number of Eggs and Methods of Deposition.—Insect eggs (Fig. 73) are generally small, and consequently are seldom noticed except when laid in masses or groups that are conspicuous. Some insect eggs are so small that several dozen could be placed side by side on the head of a common pin; the largest eggs of our common insects are not over ⅛ inch in diameter.

The number of eggs laid by one insect is as varied as their shape and size. A single female may lay as few as one egg (in exceptional cases, like the true females of certain aphids), or at the other extreme 1,000,000 or more. The honeybee queen lays 2,000 or 3,000 eggs a day, actually producing several times her own weight of eggs each day for weeks at a time. The termite queen lays as many as 60 eggs a minute until millions have been produced. The average number for all insects is probably over 100.

The eggs may all be laid at one time, as in the tussock moth; or a few a day for many days, as in the blood-sucking lice; or there may be a number of successive "batches" of eggs produced at intervals, as in the case of the common house fly, which lays from two to seven lots of eggs at intervals of 2 to 5 days, each lot consisting of about 125 eggs.

Insect eggs are generally laid in such a situation that the young, upon hatching, may find suitable food with the minimum of effort or discriminative action. More often than not, they are simply extruded in a suitable place, which is generally selected with remarkable care. This done, the mother pays no further attention to them, usually dying shortly afterward. There is ordinarily very little of parental care or family life among insects. The eggs hatch (Fig. 77) without attention or control by their parents, and from the moment of hatching the young insect must ordinarily lead an independent, self-supporting existence.

There are some very interesting adaptations of egg laying to the subsequent life of the young insect. The chestnut weevil has a beak longer than her own body, with which she reaches through the chestnut bur to chew a hole into the developing nut. In this hole is laid the egg from which the chestnut "worm" develops. The plum curculio and the strawberry weevil make remarkable provision to assure the success of the eggs and young (Fig. 5, *E*, *F*; see the discussion of egg laying under these insects). The horse botfly, whose young must reach the stomach of the horse in order to develop, lays its eggs, not in the horse's mouth, but on the hairs of the horse's

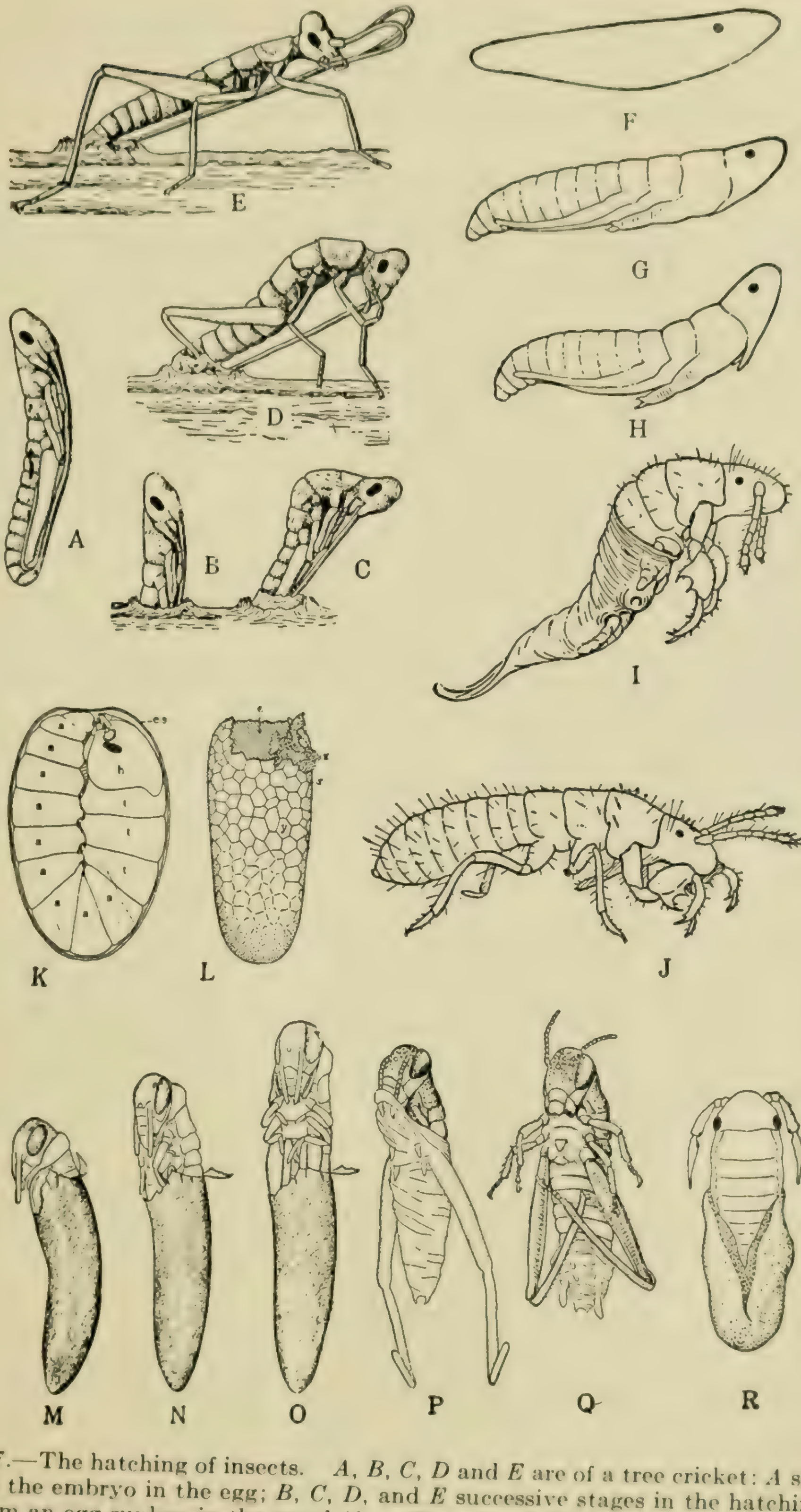

FIG. 77.—The hatching of insects. *A*, *B*, *C*, *D* and *E* are of a tree cricket: *A* shows the position of the embryo in the egg; *B*, *C*, *D*, and *E* successive stages in the hatching of the nymph from an egg sunken in the wood (*from Parrott and Fulton*). *F*, *G*, *H*, *I*, and *J* are the periodical cicada: *F*, the egg with the eye of the embryo showing through the chorion; *G*, the newly hatched nymph; *H*, the same in motion; *I*, the same, shedding embryonic membrane; *J*, the same free from embryonic membrane (*from Snodgrass*). *K*, shows the embryo peach borer larva in its U-shaped position in the egg before hatching, and *L* the empty egg shell from which the larva has hatched (*from Peterson*). *M*, *N*, *O*, *P* and *Q* show successive stages in the hatching of a grasshopper (*from S. Dak. Agr. Exp. Sta.*). *R* is of an apple aphid showing the nymph partly hatched from the egg. (*From Peterson.*)

legs. Their success in reaching their feeding grounds is thought to depend upon the activities of another insect, the stable fly. The bites of the stable fly cause the horse to nibble at its legs. The eggs of the horse bot hatch almost instantly when stroked by the moist lips or tongue, to which the small larvæ cling, and are subsequently swallowed.

One of the most remarkable cases of provision for the young is exhibited by the twig girdler. The twig girdler lays her eggs one in a place in holes which she chews into the soft bark of the terminal twigs of such trees as hickory, oak, pecan, persimmon, and many others. Before the eggs are laid, however, she completely girdles the twig, usually to a depth of 1/8 inch or more, by chewing out the wood, bit by bit, in a band around the twig (Fig. 5, *D*). This girdling requires many hours of work on the part of the female (commonly 40 or 50 hours) and when it is completed, the insect lays in the partially severed twig perhaps 12 or 20 eggs. Other twigs are then attacked in a similar manner, and the female busies herself in this way all during the long autumn months. The twigs subsequently break off in the wind and the larvæ develop in the dead, decaying wood at the surface of the soil. This represents probably the extreme of parental care on the part of an insect, in the mere act of egg laying. A closely related species in the subtropics often cuts off branches 1 or 1½ inches in diameter, several females working together to sever so large a branch.

Many other insects, especially the Hymenoptera, build elaborate nests and provision them with paralyzed insects or honey to serve as food for the young (see Figs. 22 and 151). The European earwig actually broods over her eggs and young after the manner of birds (Fig. 101). But the great majority of insects lay their eggs and die without ever seeing them again. There is in almost every case, a new "crop" of insects each year. It is the exceptional species, like the white grubs, wireworms, periodical cicada, ants, and honeybee, in which the same individuals live longer than one year, and even in these cases the adult is generally short-lived and only the young or the queens persist into the following seasons.

The Rapidity of Insect Increase.—Insects multiply very rapidly. This great increase may be due to either one or both of the following factors: (*a*) a great number of eggs or young in a family or generation; and (*b*) a short life cycle and the rapidity with which generations succeed each other. Compared with the half dozen or dozen children which characterize the families of man and our domestic animals and fowls, the hundreds of the average insect family are impressive. Again, the life cycle or generation in the larger animals is from a few months in the case of smaller rodents to as much as 30 years in the case of man, while the shortest known life cycle among insects is about 10 days!

Either one of these factors operating independently may result in a tremendous population of insects from one or a few individuals that may begin the season. For example, the corn root aphid has a family averaging from 12 to 16 young. But each of these begins reproducing at the age of 8 days, and a generation may be completed in 16 days. In this way it would be possible, theoretically, for a single female to produce in 1 year, if all her descendents survived, a chain of these aphids long enough to encircle the earth. The San José scale has fewer generations—from two to four in the northern states—yet, because of the large number of young produced by one female (400 to 500), a single pair might be the

progenitors, if all their descendents survived, of more than 1,000,000 in a single season. In the case of the house fly, both of the above factors operate to produce the alarming increase in numbers of flies as summer comes on. According to Hodge:

> A pair of flies beginning operations in April, might be progenitors, if all were to live, of 191,010,000,000,000,000,000 flies by August. Allowing ⅛ cubic inch to a fly, this number would cover the earth 47 feet deep.

Needless to say, owing to the factors of natural control, no such rate of increase ever actually occurs.

The first life stage of all insects is the egg (sometimes concealed within the mother's body). The time spent within the egg may be as short as 8 hours, as in the case of the house fly; is commonly a week or two; and very often insects go through the winter in this stage, all other stages then usually dying off before winter is passed.

Fig. 78.—Adult and young of a collembolan, *Podura* sp., one of the simplest insects, illustrating development without metamorphosis. Much enlarged. (*From Kellogg's "American Insects."*)

Insects without a Metamorphosis.—The egg may lie dormant for a long period of time, but during at least a part of the egg stage there is great activity within the eggshell, as a result of which a perfectly formed young insect is finally disclosed by hatching.[1] (Fig. 77.) When a chicken or a duckling hatches from its egg it resembles in most respects (except size) the full-grown chicken or duck. A few insects, when they hatch, also are so much like their parents that anyone would know they belonged to the same kind of insect (Fig. 78). This is especially true of a small number of wingless insects belonging to the orders Thysanura and Collembola, the fish moths and springtails. Such insects are said to undergo *no metamorphosis*, and the two orders just mentioned are collectively called the *Ametabola* (which means *without change*). Their growth from smallest to largest is hardly accompanied by greater changes in appearance than those that take place from infancy to manhood (see Table III, p. 152).

Insects with a Gradual or Simple Metamorphosis.—If the full-grown insect has wings, the young never resemble it completely at hatching, for (unlike birds) *no insect has visible wings when it emerges from the eggshell* (see Fig. 77). All winged insects, therefore, undergo a metamorphosis during their development. *Metamorphosis* may be defined as *a conspicuous change in the form and appearance of an animal between birth (or hatching) and maturity.* Frogs or toads, with their curious young

[1] The term *hatching* properly refers only to breaking out of the eggshell or embryonic membranes. The escape of a winged insect from its cocoon or pupa case should be called *emergence*, not hatching.

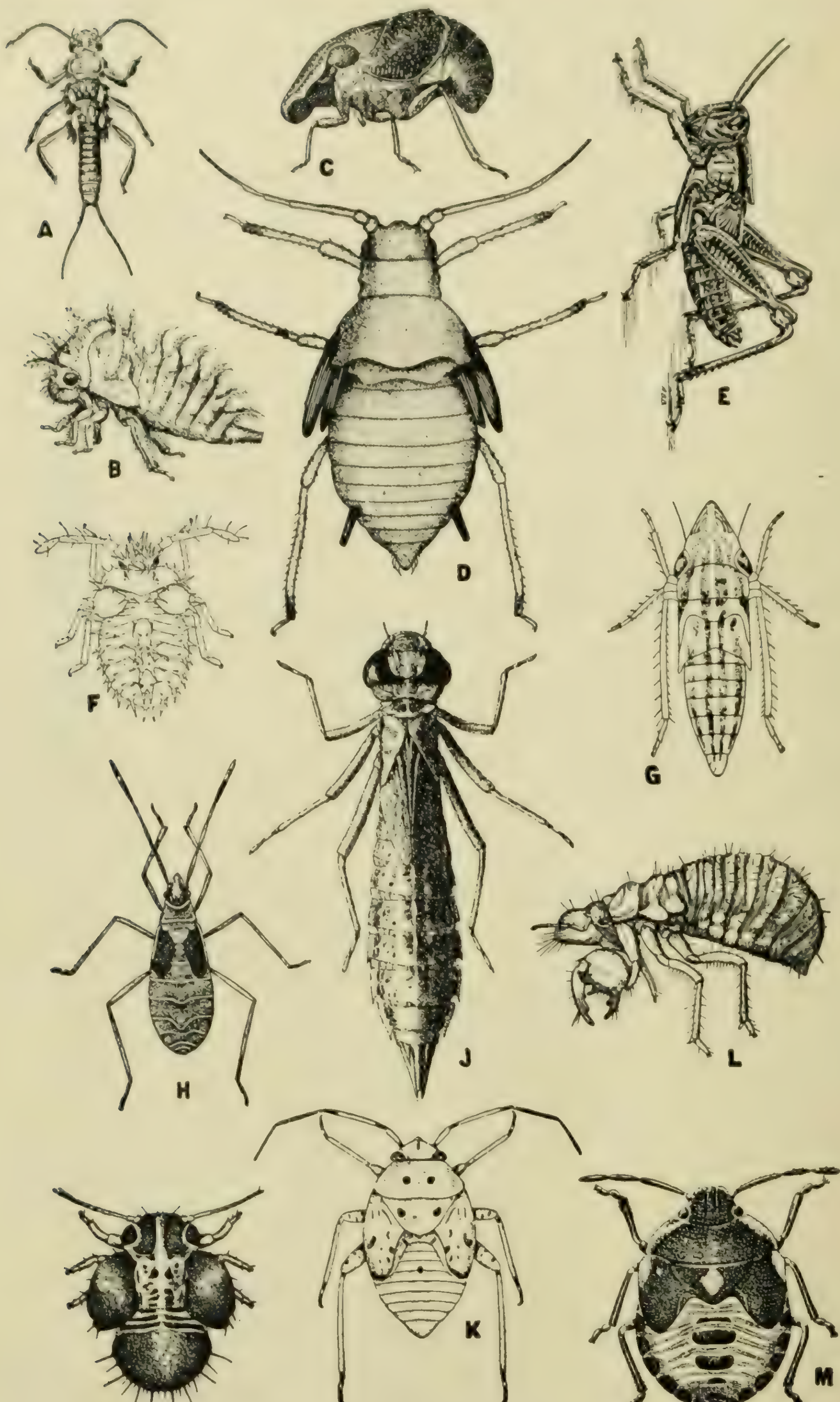

Fig. 79.—*Nymphs:* examples of insects that develop the wings externally during the growing period and transform to the adult usually without a pupa stage. *A*, nymph of a stone-fly, order Plecoptera (*from Kellogg's "American Insects"*); *B*, nymph of a treehopper, *Ceresa basalis* Walk., order Homoptera (*from N. Y. State College Forestry*); *C*, nymph of a fulgorid, *Bruchomorpha oculata* Newm., order Homoptera (*from N. Y. State College Forestry*); *D*, nymph of an aphid, *Aphis cucumeris*, order Homoptera (*from U. S. D. A.*); *E*, nymph of a grasshopper (*from U. S. D. A.*); *F*. nymph of a lace bug, *Corythuca pergandei* Heid., order Hemiptera (*from Ohio Biol. Sur. Bull.* 8); *G*., nymph of a leafhopper, *Dræculacephala*

tadpole stages, have a metamorphosis, while birds, rabbits, men, and the like, have no metamorphosis during their post-embryonic development.

In many insect species the young are very similar to the adult except for the complete absence of wings; in other cases there are striking differences in the color or shape, or in the structure of some of the appendages. In either case, after a period of growth the wings may appear attached to the outside of the body as small *wing pads* which become larger and larger. And the more developed the young insect becomes the more it resembles its parents (Fig. 80). Such a development is called a *gradual* or *simple metamorphosis.* The young of such insects are called *nymphs* (Fig. 79). They commonly have the same habits as their parents, and the old ones and young ones may frequently be seen feeding together, not unlike a hen and her chicks. Grasshopper nymphs and adults both eat grasses and clovers and may be found hopping about together in the pastures. Squash-bug nymphs and adults both suck the sap of the squash plant. Bedbug nymphs and adults all suck human blood. This group as a whole is known as the *Heterometabola* (meaning *different change*). It includes many important insects of the orders Orthoptera, Isoptera, Mallophaga, Thysanoptera, Homoptera, Hemiptera, Anoplura, and others (see Table III, p. 152).

Insects with a Complete or Complex Metamorphosis.—Finally, we have a large group of insects, most of which have different habits when they are young than when they are full-grown. For example, the young may swim in the water and the adults live in the air, like the mosquitoes. Or the young may tunnel through the soil and eat grass roots like the white grubs, while their parents, the May beetles, fly about and feed on the leaves of trees. Or the young may live in the stomach of a horse like the bots and the parents fly freely in the air. Obviously these insects could not exist in such different environments unless they were very different in structure when young and when full grown. Indeed, they are generally so very different in appearance in their several life stages that no one, without previous information, would ever suspect them of being even closely related animals, much less the successive stages of *the same individual.* The young of this group show no trace of wings externally during any period of growth, although the wing buds may be found, by dissection, inside the body wall (see Figs. 58, *f.b*, and *h.b*; and 81, II and III). Furthermore, the oldest larva shows no greater resemblance to the adult than the smallest one, except in size (Fig. 82). Such young

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mollipes Say, order Homoptera (*from U. S. D. A.*); *H*, nymph of the cotton stainer, *Dysdercus suturellus* H. Schf., order Hemiptera (*from Insect Life*); *I*, nymph of the pear psylla, *Psyllia pyricola* Linn., order Homoptera (*from Slingerland*); *J*, nymph of a dragonfly, *Anax junius*, order Odonata (*from Ill. State Nat. Hist. Survey*); *K*, nymph of the tarnished plant bug, *Lygus pratensis* Linn., order Hemiptera (*from Ill. State Nat. Hist. Survey*); *L*, nymph of the periodical cicada, order Homoptera (*from U. S. D. A.*); *M*, nymph of the green plant bug, *Nezara hilaris* Say, order Hemiptera (*from U. S. D. A.*).

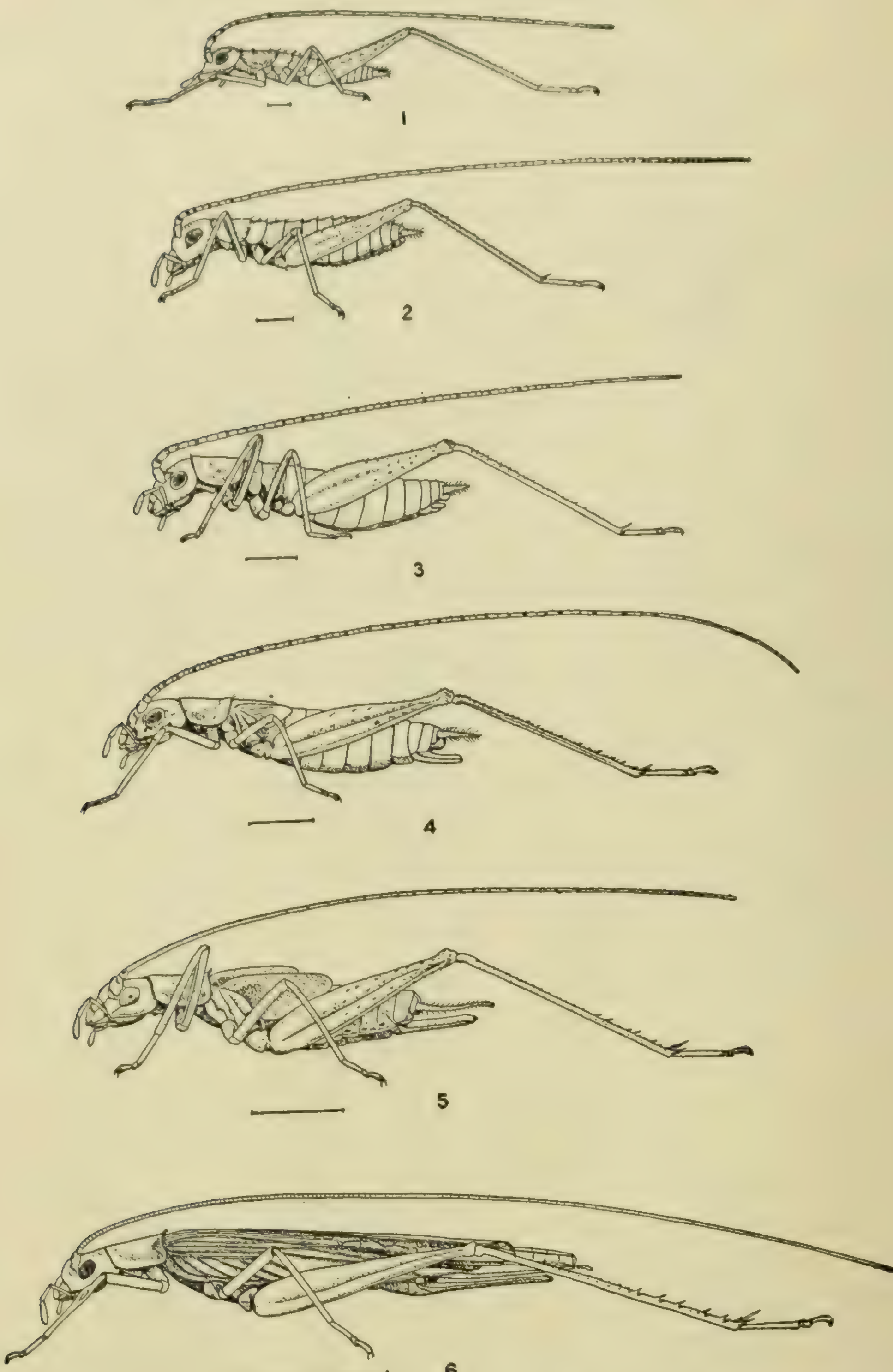

FIG. 80.—Instars or stages of growth of the snowy tree cricket, *Œcanthus niveus* De G., illustrating a gradual metamorphosis. 1 to 5 the first to fifth nymphal instars, respectively; 6, the adult. Note the appearance of the wing pads at 4 and their expansion to full size at 6; also the very gradual assumption of the adult condition. (*From N. Y.* (*Geneva*) *Agr. Exp. Sta. Bull.* 388.)

insects are known as *larvæ* (singular *larva*), in contrast with nymphs (Fig. 83).[1]

When a larva is full-grown, a striking change takes place, and the insect, after shedding its skin, appears with the wings exserted as large wing pads and with the usually long legs and feelers of the adult now recognizable. But legs, wings, and antennæ always remain functionless for a definite period of time while the internal organs are being transformed to the adult condition. This transformation stage is known as the *pupa* (plural, *pupæ*) (Fig. 84). At its completion, the pupal skin is shed and the adult formed by rapid expansion of the wings to full size, the general hardening of the body wall, the development of the color pattern and numerous other changes. Such development is called a *complete* or *complex metamorphosis.* The largest orders of insects have such a complete metamorphosis; for example, the Coleoptera, Lepidoptera, Hymenoptera, and Diptera; besides some smaller orders like the Siphonaptera, Neuroptera, and others (see Table III, p. 152). All these insects that have a complete metamorphosis are referred to collectively as *Holometabola* (meaning *complete change*).

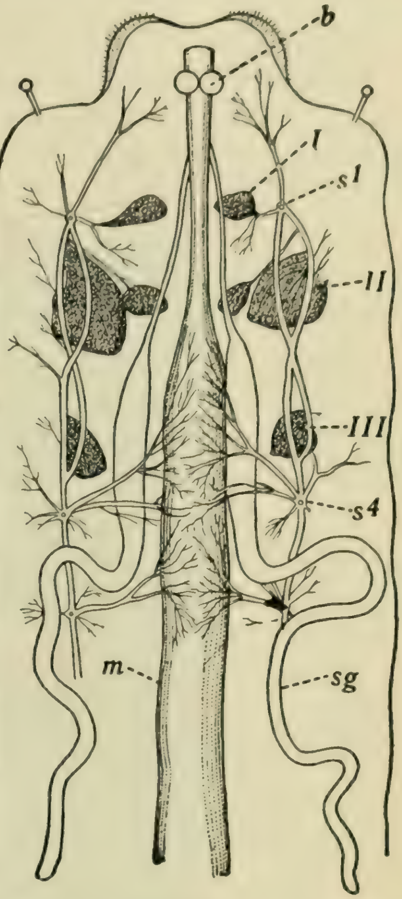

FIG. 81.—Dissection of a full-grown caterpillar, *Pieris* sp., from above, to show the wing buds which are developing inside the body wall. *b*, brain; *m*, alimentary canal; *s1*, prothoracic spiracle; *s4*, first abdominal spiracle; *sg*, silk gland; *I*, bud of the prothoracic segment; *II*, bud of the front wing; *III*, bud of the hind wing. (*From Folsom's "Entomology," P. Blakiston's Son & Co., after Gonin.*)

Life Stages and Instars.—For a further understanding of the growth and metamorphosis of insects, it is essential to have clearly in mind what is meant by *life stages* and by *instars*. The life stages are those several periods of an insect's life which are radically different from each other in appearance and usually also in behavior or activity. Thus the insects with a complete metamorphosis have *four life stages;* the *egg*, the *larva*, the *pupa*, and the *adult*. While insects with a gradual metamorphosis

[1] The authors realize that the term larva is often used for the first stage of any insect or other animal having a metamorphosis, and wish that a special term could have been employed for the young of insects with a complete metamorphosis. However, the term larva is so firmly established as a general term for caterpillars, grubs, maggots, and the like that there would be no hope of any special term for this purpose becoming adopted. *Larva* as used in this book, therefore, means the young of insects that have a complete or complex metamorphosis.

and those without metamorphosis have *three life stages*, known as the *egg*, the *nymph*, and the *adult*. *Among insects, all increase in size takes place in the life stage that immediately follows hatching*, that is either while a nymph (if the insect has a gradual metamorphosis) or as a larva (if the insect has a complete metamorphosis). *No growth occurs in the adult stage after the insect once acquires functional wings, and none in the pupa stage.* Little flies do not ever grow into larger flies, nor little moths into larger ones. With the appearance of the full-spread wings the size of the

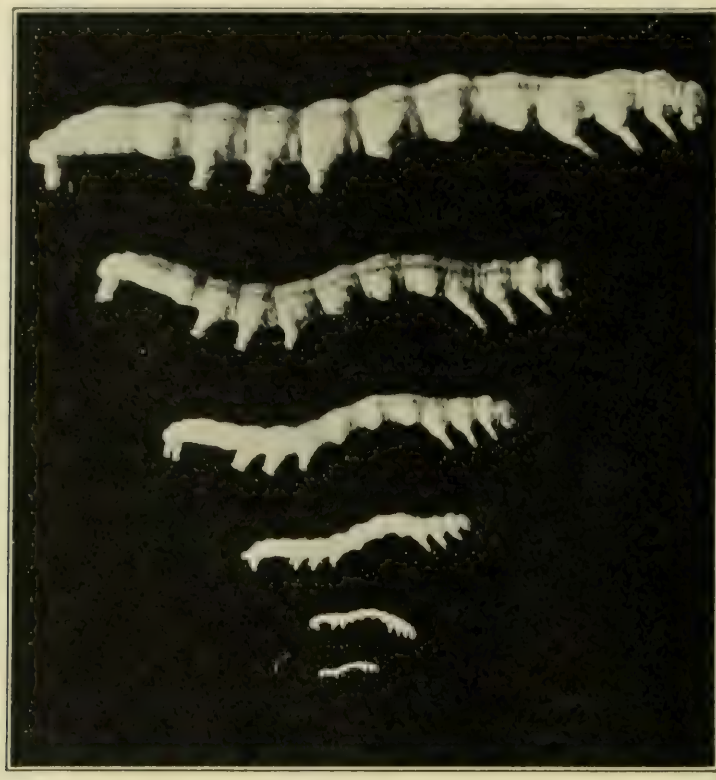

FIG. 82.—Instars or stages of growth of the green clover worm, *Plathypena scabra* Fab., illustrating a complete metamorphosis. Note the entire absence of wing pads even in the largest instar; the fact that the largest larva is no more like the adult moth in form than the smallest; and that a pupa stage intervenes between the last larva and the adult. (*From U. S. D. A. Farmers' Bull.* 982.)

insect is fixed for the rest of its life except as the body expands to accommodate a large meal or developing eggs.

Since growth occurs exclusively during the nymphal or larval period, it follows that there must be various sizes of nymphs or larvæ (Figs. 80 and 82) in the case of every species and in the development of every individual. An insect does not grow by regular, gradual, imperceptible degrees like a child. Its body wall will not expand like a mammal's skin to permit this. It has been pointed out (p. 72) that the body wall is composed of a double outer layer, the cuticula (itself consisting of two layers—an outer epidermis and an inner dermis); and beneath the dermis a layer of living sensitive cells known as the hypodermis; and that the

cuticula becomes chitinized and inelastic over most of the outside of the body to form a stiff, hard, external armor for the insect.

It follows, therefore, that growth inside this inexpansible shell cannot be regular and continuous. In order to make any considerable increase in size the shell must be split off. This process is known as *molting* and the old cuticula so cast off is known as the *exuviæ* (meaning *clothes*). Before the old cuticula is split off, a new epidermis is secreted inside it by the hypodermal cells. Then a fluid, known as the molting fluid, is poured out by certain special cells in the hypodermis. The molting fluid loosens the outer shell by corroding the dermis of the old cuticula and the complete body covering is then split open and the insect crawls out. At this point there is a considerable expansion in size before the new epidermis becomes chitinized and "set" to a definite size. Subsequently there is a relatively long period during which the insect is feeding and accumulating reserve materials within its body but without any noticeable increase in size. This is followed by another molt and period of constancy in size, and so on.

The molts occurring during the growing period divide this life stage (nymph or larva as the case may be) into a number of sharply separated sizes or steps that are called *instars* (Figs. 80 and 82). Upon hatching from the egg, the insect is said to be in the first instar. This instar is terminated by the first molt, which ushers in the second instar, distinctly marked off from the first at least by its larger size, and often also by differences in structure or color. The second molt introduces the third instar and so on, until commonly 3, 4, 5, or 6, and sometimes as many as 20 molts, have occurred (Table III).

When growth (increase in size) is completed, if the insect be a nymph a final molt discloses the adult; if it be a larva the corresponding molt gives rise to the pupa stage and when the transformations of this stage are perfected a final molting of the pupal epidermis discloses the adult.

Any insect during its development passes through either three or four *life stages*, one, and only one, of which is always made up of a number of *instars*. Any considerable difference in size without much change in appearance indicates a different *instar;* while a radical change in structure and appearance, without much change in weight, indicates a different *life stage*.

Sometimes it is difficult to decide whether the metamorphosis of a given insect should be called complete or gradual. We must bear in mind that nature does not make sharp division lines; that there is likely to be every conceivable gradation from one condition to another which is remarkably different. It is so with the metamorphosis of insects. The groups described above, however, are very important for convenience of study and reference, and most insects can easily be fitted into one or another of them.

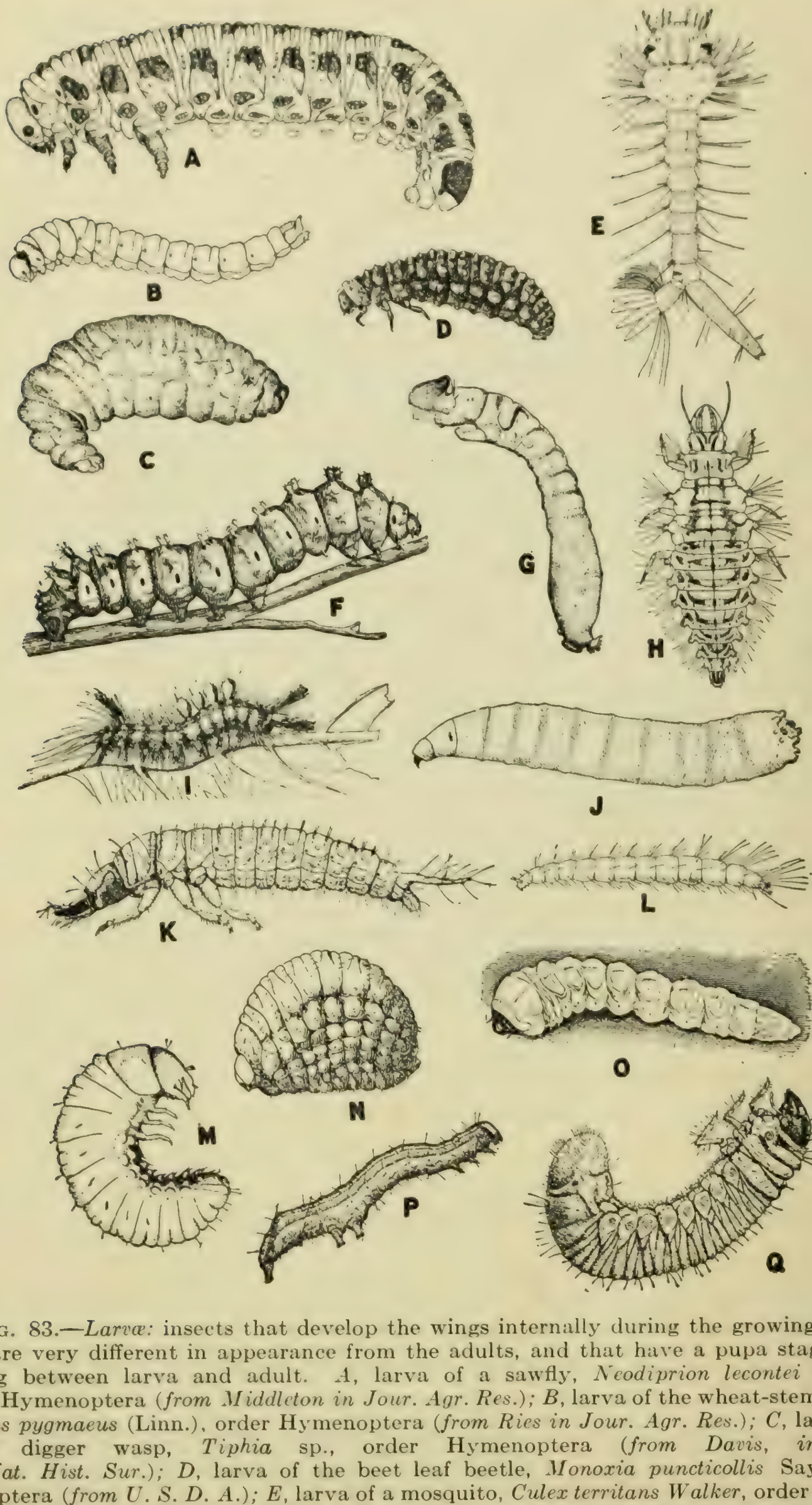

FIG. 83.—*Larvæ:* insects that develop the wings internally during the growing period, that are very different in appearance from the adults, and that have a pupa stage intervening between larva and adult. *A*, larva of a sawfly, *Neodiprion lecontei* (Fitch), order Hymenoptera (*from Middleton in Jour. Agr. Res.*); *B*, larva of the wheat-stem sawfly, *Cephus pygmaeus* (Linn.), order Hymenoptera (*from Ries in Jour. Agr. Res.*); *C*, larva of a black digger wasp, *Tiphia* sp., order Hymenoptera (*from Davis, in Bull. Ill. Nat. Hist. Sur.*); *D*, larva of the beet leaf beetle, *Monoxia puncticollis* Say, order Coleoptera (*from U. S. D. A.*); *E*, larva of a mosquito, *Culex territans Walker*, order Diptera (*from Bull. Ill. State Lab. Nat. Hist.*); *F*, larva of the cecropia moth, *Samia cecropia* (Linn.), order Lepidoptera (*from Saunders*); *G*, larva of a black fly, *Simulium venustum* Say, order

Nymphs vs. Larvæ.—The best criterion to divide the winged insects into two groups, in respect to metamorphosis, is (1) whether the wing pads are borne externally during the growing stage or concealed beneath the body wall. If the wing pads are developed on the outside of the body wall (see Figs. 79 and 80) we call the growing stage a *nymph* and we say that insect has a *simple* or *gradual metamorphosis.* If the wing pads are developed internally during the growing stage, (Figs. 58, *f.b.* and *h.b*; and 81, II and III) we call that stage a *larva* (see Figs. 82 and 83) and say that insect has a *complete* or *complex metamorphosis.* A nymph, then, is the growing stage of such insects as have a gradual or simple metamorphosis, and develops its wings (if it have any) on the outside of the body wall as visible pads. Other general differences between nymphs and larvæ are (2) that the nymph generally has a shape and body construction similar to that of the adult; (3) each successive instar usually looks more like the adult than the one that preceded it; (4) nymphs have very few organs that are not also possessed by the adult; (5) a nymph has compound eyes unless its parents are without compound eyes; (6) it always has the same type of mouth parts as the adult; (7) it generally occupies the same kind of habitat, takes the same kind of food, and leads the same manner of life as the adult; and, finally, (8) the nymphal period generally passes over into the adult period without any prolonged inactive or pupal stage intervening.

In contrast with the nymph, the larva, or growing stage of insects with complete or complex metamorphosis, (1) develops its rudimentary wings during this stage inside the body wall of the thorax; (2) it generally has a more or less wormlike form of body, often strikingly different from that of the adult; (3) the later instars are no more like the adult, as a rule, than the earlier ones; (4) the larva often has provisional structures or organs, of use only in this stage and which are lost or supplanted before the adult stage is reached; (5) the larva never has functional compound eyes, though it may have simple eyes or ocelli; (6) it may occupy the same habitat as the adult, but very often lives in a totally different sort of situation; (7) the larva commonly has a different type of mouth parts than the adult and often takes a wholly different kind of food; and, finally, (8) the larva is always separated from the adult by a pupa stage during which the insect takes no food and is usually quiescent.

Diptera (*from H. Garman*); *H*, larva of a lace-winged fly, *Chrysopa quadripunctata* Burm., order Neuroptera (*from R. C. Smith*); *I*, larva of the California tussock moth, *Hemerocampa vetusta* Boisd., order Lepidoptera (*from Volck, Calif. Agr. Exp. Sta.*); *J*, larva of the apple maggot, *Rhagoletis pomonella* Walsh, order Diptera (*from Penn. State Dept. Agr.*); *K*, larva of a ground beetle, *Harpalus pennsylvanicus* Dej., order Coleoptera (*from Davis, Ill. State Nat. Hist. Survey*); *L*, larva of a flea, order Siphonaptera (*from Bishopp, U. S. D. A.*); *M*, larva of *Colaspis brunnea* (Fab.), order Coleoptera (*from Ill. State Nat. Hist. Survey*); *N*, larva of the granary weevil, *Sitophilus granarius* Linn., order Coleoptera (*from U. S. D. A.*); *O*, larva of the giant root borer, *Prionus laticollis*, order Coleoptera (*from N. J. Agr. Exp. Sta.*); *P*, larva of the alfalfa looper, *Autographa gamma californica* (Speyer), order Lepidoptera. Note reduced number of prolegs (*from Hyslop, U. S. D. A.*); *Q*. larva of a scarab beetle, *Adoretus caliginosus* (O.S.), order Coleoptera (*from T. B. Fletcher*).

The Meaning of a Complete Metamorphosis.—The explanation of a complete metamorphosis is probably that growth is all confined to one life stage (the larva) and reproduction to another (the adult). For the

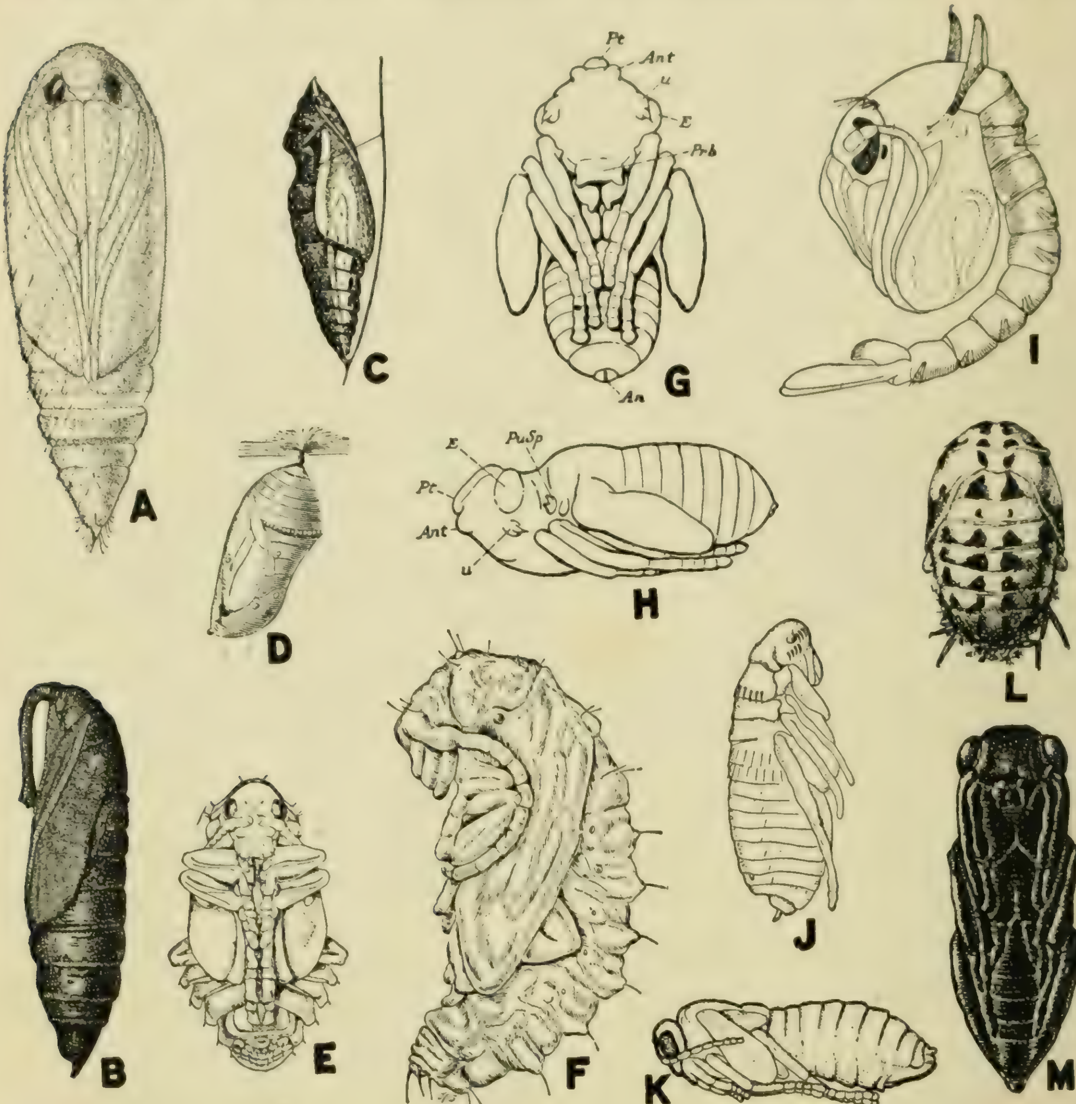

Fig. 84.—Pupæ of insects: *A*, *B*, *C*, and *D* of Lepidoptera; *E*, *F* and *L* of Coleoptera; *G*, *H* and *I* of Diptera; *J* of Siphonaptera, *K* and *M* of Hymenoptera. *A*, pupa of the pink bollworm, ventral view (*from Heinrich in Jour. Agr. Res.*); *B*, pupa of southern tobacco worm, side view (*from U. S. D. A.*); *C*, naked pupa or chrysalis of the alfalfa caterpillar: Note how it is suspended by a thread or girdle of silk (*from U. S. D. A.*); *D*, pupa or chrysalis of the monarch butterfly as it hangs suspended by the posterior end (*from French*); *E*, pupa of the beet leaf beetle, ventral view (*from U. S. D. A.*); *F*, pupa of the cherry-leaf beetle, side view (*from U. S. D. A.*); *G*, pupa of the apple maggot, ventral view; *H*, the same in side view (*from Snodgrass, in Jour. Agr. Res.*); *I*, pupa of the house mosquito; a pupa that swims in water (*from U. S. D. A.*); *J*, pupa of the dog flea (*from U. S. D. A.*); *K*, pupa of the pear slug (*from Iowa Agr. Exp. Sta.*); *L*, pupa of the convergent lady beetle: it is fastened by silk to the leaf and can rise up on the rear end when disturbed (*from U. S. D. A.*); *M*, pupa of a hymenopterous parasite, *Pardianlomella ibseni* Gir. (*from U. S. D. A.*).

functions of eating, growing, and storing up energy, a simple cylindrical body with few appendages is well adapted. And since the parent insect generally places the young in the midst of an abundance of food, highly

specialized sense organs are not usually required. But to secure a mate, to locate a suitable place to deposit the eggs, and to care for the necessary dispersal of the species, a highly sensitive, active, complex body is required. Hence we have on the one hand the sluggish, stupid, gluttonous caterpillar of simple structure (Fig. 83); and on the other, the alert, highly specialized fly, bee, moth, or beetle. So very different have these stages become in many cases that the change from one form to the other is profound. In some insects nearly all the larval tissues disintegrate and the corresponding adult tissues and organs are built up anew from small groups of cells (histoblasts) that have remained dormant and rudimentary during larval life, but are now able to multiply rapidly by utilizing the nutritive products resulting from the histolysis of the larval cells and from the fat-body.

What takes place may be likened to a proposal to convert a farm wagon into an airplane. It is conceivable that there might be about the same amount of building materials in the two vehicles, but to change one into the form of the other would involve a complete reconstruction of all parts. Certainly, while such reconstruction was taking place, the vehicle could not be used. So it is with the insect. So profound is the change from larva to adult in many cases that the organism can accomplish no other functions while it is going on. Locomotion ceases, feeding is suspended, respiration is reduced, and the insect undergoes a transformation period, externally quiescent but internally probably as active as any period subsequent to embryonic development. All available energy is devoted to the development of the wings, legs, eyes, antennæ, mouth parts, and other appendages of the adult, and to the maturing of the reproductive system and changes in other internal organs. The insect during this period is known as a *pupa* (Fig. 84).

Because it neither feeds nor moves about, the pupa stage is neither injurious nor beneficial to man.

Methods of Protection for the Pupa.—The life of the insect during the helplessness of the pupa stage is generally safeguarded by the larva. Sometimes the pupa is found naked and exposed, as with many butterflies, lady beetles and the like. These (Fig. 84, *A*, *C*, *D*, *L*) usually have the tips of their bodies fastened to a leaf but are not covered in any way. Commonly the larva retreats into a protected situation under overhanging bark, or into logs, stones, grass or leaf mold, or into the soil, before entering upon this defenseless period of its life (Fig. 85, *H*, *K*). Often a case is formed about the larval body before pupation. The case may consist of a folded leaf (Fig. 85, *B*), fine pebbles (*F*, *N*), fine shavings of wood, bits of soil, hairs from the body of the larva, or other materials that surround the larva as pupation approaches (*E*, *G*, *K*, *L*). These are generally cemented or tied together by a silken secretion from the mouth of the larva; and in many moths and Hymenoptera the silk is abundant and

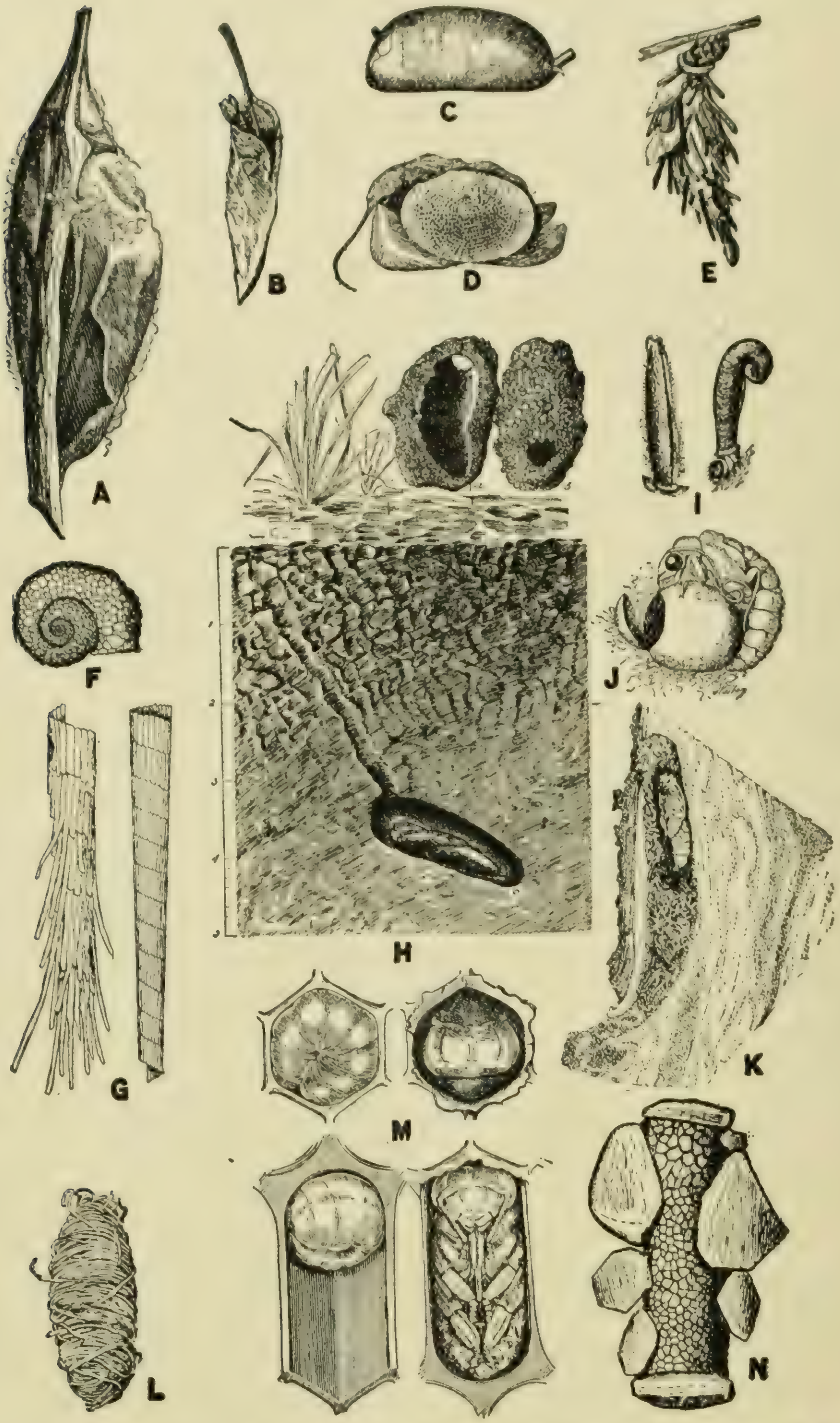

FIG. 85.—Some methods of protection for insect pupæ. *A*, cocoon of the cecropia moth (*from Saunders, "Insects Injurious to Fruits"*); *B*, folded leaf in which the apple leaf sewer, *Ancylus nebeculana* Clemens, feeds as a larva and which also protects the pupa stage. Empty pupal shell from which adult emerged projects at upper left (*from U. S. D. A.*); *C*, puparium of *Tropidia quadrata* Say; a protective case formed from the larval skin (*from Metcalf in Me. Agr. Exp. Sta. Bull.* 253); *D*, cocoon of the clover leaf weevil, partly surrounded by clover leaves (*from Tower and Fenton, U. S. D. A.*); *E*, the bagworm, a case of silk covered with spruce needles carried about by larva during its life and later closed to protect pupa (*redrawn after Riley*); *F*, larval case of a caddice-fly, *Helicopsyche borealis*, formed in the shape of a snail shell and covered with grains of sand (*from Lloyd, "North American Caddice Fly Larvæ"*); *G*, larval and pupal cases of a caddice-fly, *Phryganea vestila*,

forms a complete, sometimes dense, case about the pupa, known as a *cocoon* (Fig. 85, *A*, *D*, *J*).

In many of the flies, instead of spinning a silken cocoon or constructing a case of extraneous material, the larva practices an interesting economy by retaining about itself one of its own cast skins, which is slightly modified by inflation and hardening with chitin, to form a waterproof and air-tight case known as a *puparium* (Fig. 85, *C*). This next-to-the-last larval skin is not discarded at the time of pupation as in most insects, but is retained until the adult breaks out of the pupal skin.

It is important to note that the actual change to the pupa does not coincide with the completion of the pupa case. The pupa stage may be said to begin when the larval skin has been molted off, but a great portion of the transformation toward the adult has already taken place before this molt occurs; notably the eversion of the wing pads from their position inside the body wall to a position outside the pupal integument but still enclosed by the unshed larval skin. The plum curculio buries itself in the soil for about 4 weeks; but 2 weeks of this time it remains as a larva before it pupates. The Hessian-fly larva may remain many months after the puparium is formed before the pupa is formed. And many moths and sawflies that winter in a cocoon do so in the larval stage, not pupating until spring. This period of variable duration between the retreat to the pupal position or formation of the pupa case and the actual change to the pupa is known as the *prepupal period*.

The order to which a given pupa belongs can usually be told by characteristics which are given in connection with the discussion of the orders in Chap. VIII, and the actual species of insect may generally be recognized, by an expert, from the pupa.

The relation of the life stages to each other and to the different instars, their significance to the insect and to man, and the correspondence of life stages in the three types of metamorphosis discussed above are shown graphically in Table III.

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made of slender sticks and bits of leaves arranged in spiral form (*from Lloyd*); *H*, pupa of southern tobacco worm in its earthen cell formed by the caterpillar. The depth is indicated by the inch marks at the left. Above are shown two earthen cells removed from the ground; note hole by which the larva entered (*from Morgan, U. S. D. A.*); *I*, case-bearers; at left the cigar case-bearer, at right the pistol case bearer with head and thorax of larva projecting below (*from N. Y. (Geneva) Agr. Exp. Sta.*); *J*, cocoon of the California green lacewing fly; the pupa has just emerged through the circular hole in the cocoon (*from Wildermuth in Jour. Agr. Res.*); *K*, pupa of the round-headed apple-tree borer; note the sawdust and shavings with which the larva had closed its tunnel behind the pupa, and also plugged the exit hole for the adult, near the head of the pupa (*drawn from photo by Slingerland*); *L*, cocoon of the Hawaiian sugar cane borer (*from Van Dine, U. S. D. A.*); *M*, larvæ and pupæ of the honeybee in the hexagonal cells made of wax by the worker bees; at left, end and side views of larvæ; at right, end and ventral views of pupæ (*from White, U. S. D. A.*); *N*, pupal case of a caddice-fly, *Neophylax concinnus*, made of minute grains of sand cemented together with a few heavier pebbles for ballast (*from Lloyd*).

TABLE III.—THE LIFE STAGES OF INSECTS

Group name and examples	The period of *inception*. Quiescent. Does not feed. Neither injurious nor beneficial		The period of *growth* The insect is always active during this period The insect always *feeds* during this period Most insects are either *injurious* or *beneficial* during this period This is the only period in which different instars occur								The period of *transformation*. Usually quiescent. Never feeds. Neither injurious nor beneficial		The period of *reproduction*. Active. Usually feeds. Often injurious or beneficial
Ametabola (without a metamorphosis): Silverfish, springtails	EGG	Hatching	YOUNG	Molt	YOUNG	Molt	YOUNG	Molt	YOUNG	Molt			ADULT
Heterometabola (with a gradual metamorphosis): Grasshoppers, termites, thrips, chewing lice, blood-sucking lice. aphids, cicadas, chinch bug, squash bug	EGG	Hatching	NYMPH	Molt	NYMPH	Molt	NYMPH	Molt	NYMPH	Molt			ADULT
Holometabola (with a complete metamorphosis): Beetles, moths, butterflies, ants, wasps, bees, fleas, flies, mosquitoes	EGG	Hatching	LARVA	Molt	LARVA	Molt	LARVA	Molt	LARVA	Molt	PUPA	Molt	ADULT

It should be emphasized that the number of molts during the growth period varies greatly in different species, though usually the same in any given species. Four instars are represented here simply to illustrate the successive moltings and increase in size. The *exact* number shown has no particular significance.

CHAPTER VII

THE PLACE OF INSECTS IN THE ANIMAL KINGDOM

The tendency to classify is inherent in the human mind. We are constantly classifying the inexhaustible assemblage of objects about us, whether we are aware of it or not. We say that certain things are useful and others of no use, some ugly and some beautiful, some hard and some soft, and so on. This ability to associate in our thinking things and ideas that are alike, and to differentiate the unlike from them, is a very valuable attribute upon which much of human progress has depended. In science, law, business, and every other human activity where a large number of objects or ideas of varied kind must be handled, a *classification* (*i.e.*, a logical sorting and arrangement of the objects or concepts) is essential to efficient progress.

Too often classifications are made hastily, with little thought, and based upon the most obvious and superficial characters. For example, to group together in a chemical storeroom all bottles of a certain height and all boxes of a certain size, regardless of whether they contain acids, bases, salts, metals, or organic compounds; or to group together a flea, a toad, and a kangaroo because they all jump; and a bird, a bat, and an airplane because they all fly; are obviously not the most fundamental, important, or useful groupings of these objects that can be made. Such groupings are known as *artificial classifications*.

No class of objects on earth presents so great and varied an assortment as the living things that inhabit its surface. The biggest job of classifying ever undertaken is the systematic study of plants and animals, including insects; and probably no other class of things or ideas has received such painstaking and exhaustive study as the classification of these living things. From the time of Aristotle (384 to 322 B. C.) and Pliny (23 to 79 A. D.), through all the generations since, scores of men the world over have given their entire lifetimes to the great problems of systematic biology. The labors of these thousands of students have far from completed the task.

The concensus of opinion of students of the present day is that life probably originated only once upon the earth and therefore that all living things have had a common origin and have grown to their present complexity of forms by an orderly and extremely slow process of ascent and differentiation; or as we say by *evolution*, in which the principal potent factors have probably been variation, natural selection, and heredity.

If life originated but once on the earth and all plants and animals have been derived from a common ancestor by a gradual process of specialization and differentiation, it follows that they must present but one true arrangement with respect to their blood relationships to each other. To discover and record this arrangement and reveal the pathways along which each creature has developed is to make a *natural classification*—the ideal of systematic botanists, zoologists, and entomologists.

All persons would probably agree on the first step in such a natural classification. That is, to make two great categories of living things, which are called the Animal Kingdom and the Plant Kingdom. If plants and animals all arose from the same original spark of life, the divergence of these two main branches of living things must have come very early, because they have so many points of difference. It is generally easy to distinguish the common plants from the common animals, though less easy to point to distinct differences by which we can separate them all. Indeed, there are some minute, intermediate forms of life that botanists and zoologists cannot definitely place as either plant or animal. The truth probably is that they are neither plant nor animal but intermediate forms partaking to some extent of the characteristics of both groups. This fact adds support to the great truth of evolution and the theory of the common origin of all life.

Differences between Plants and Animals

Animal Kingdom.—Characteristically free-moving organisms.	**Plant Kingdom.**—Characteristically sessile.
Generally assimilate organic foods.	Generally take inorganic foods.
Very rarely possess chlorophyll.	Generally possess chlorophyll.
Have protoplasmic, or protein cell walls.	Have cellulose or hydrocarbon cell walls.

The last of the characteristics mentioned above appears to be the most universal difference between all animals and all plants. Since insects are animals, the plant kingdom is dismissed from further consideration at this point.

The Phyla of Animals

Taking the animal kingdom as a whole, we find that about three-fourths of a million species or kinds have been discovered and named. Practically all of the known animals fall naturally into about a dozen important groups or branches, which are called by the Latin name that means branch, namely *phylum* (plural phyla). Thus one large phylum (the Chordata) includes all the animals that have a backbone; such as birds, fishes, and man. Another, the phylum Mollusca, includes such aquatic shelled animals as oysters and clams, and also the slugs and snails. The phylum Echinodermata embraces those radially arranged marine animals known as starfishes, sand dollars, and many others. The phylum Annelida includes true worms such as earthworms and leeches.

Other phyla somewhat less well known, are outlined in Table IV, which also gives the well-known examples and a general idea of the size of each phylum. The species placed in each branch or phylum all have what are thought to be fundamental characteristics in common; that is, they are kin, and resemble each other in many respects, as a horse does a cow. It may seem in many cases that the resemblance is rather slight, such as that between a bird and a cat. But in all cases it is much

TABLE IV.—THE ANIMAL KINGDOM

Phylum	*Class*	*Examples*	*Estimated Number of Living Species Described*	
		VERTEBRATES		
Chordata				
	Mammalia	Man, cat, horse, bat, whale	3,750	
	Aves	Birds, fowls	13,500	
	Reptilia	Turtles, snakes, lizards, alligators	4,000	
	Amphibia	Frogs, toads, salamanders	1,750	
	Pisces	Fishes	13,500	
		INVERTEBRATES		
	Minor Classes	Tunicates, Balanoglosus, etc.	1,500	
		Total Chordata		38,000
Arthropoda		**(See Table V for Classes and Examples)**		**675,000**
Mollusca		Snails, slugs, clams, oysters		80,000
Echinodermata		Starfish, sand dollar, sea urchin		5,000
Annelida (Annulata)		Earthworm, leeches		5,000
Molluscoidea		Bryozoa, brachiopods		2,500
Platyhelminthes		Flatworms, flukes, tapeworms		6,500
Nemathelminthes		Roundworms, Trichina, Filaria		3,500
Trochelminthes		Rotifers, wheel animalcules		1,500
Cœlenterata		Jelly-fishes, coral animals, Hydra		5,000
Porifera		Sponges		3,000
Protozoa		Amœba, Paramœcium, Euglena, malarial organisms, trypanosomes		15,000
		Grand total		840,000

greater between the animals of the same phylum than between those of different phyla. Thus the bird and the cat have fundamental points of likeness in the eyes, the heart, the backbone, and the limbs, which are obviously greater than any resemblance between either of them and a starfish, a worm, a sponge, or an insect. Each of the latter is accordingly placed in a different phylum from that to which the bird, cat, and other vertebrates belong.

The phylum that is most familiar to us is the one to which we belong, the phylum Chordata, the better-known part of which is the Vertebrates. The most evident characteristic of this phylum is that the animals in it have a backbone or dorsal chain of bony vertebræ surrounding the spinal

cord. The vertebrates include, besides man and all the other mammals: birds; snakes, lizards, alligators, and their kind; frogs and toads; and fishes. Certain of these obviously resemble each other much more closely than they do the others. Thus a cow, a horse, and a cat are clearly more alike than a cow, a chicken, a snake, and a fish. To express these differences between animals placed in the same phylum, secondary groupings known as *classes* are used. Thus in the phylum Chordata (the Vertebrates) we have the following important *classes:*

Classes of Vertebrate Animals

Class Mammalia, the hairy, four-footed, milk-secreting animals, such as man, monkeys, horses, whales, elephants, bats, squirrels, dogs, and anteaters.

Class Aves, the winged and feathered animals, such as the chicken, sparrow, robin, eagle, parrot, ostrich.

Class Reptilia, the cold-blooded, scaly, air-breathing animals, such as snakes, lizards, crocodiles, and turtles.

Class Amphibia, the cold-blooded, soft-skinned vertebrates, whose young breathe by gills and adults by lungs, such as frogs, toads, and salamanders.

Class Pisces, the cold-blooded, aquatic animals, typically covered with scales and having fins, such as carp, salmon, eel, bass, and trout.

Orders, Families and Genera

The examples given under the class Mammalia show clearly that, while these animals are fundamentally alike in the possession of hair and mammary glands, there are still wide differences between them. For example, some of the Mammalia lay eggs, like the anteaters, while most bring forth the young alive, not enclosed in an eggshell. Some are adapted for life in the water, like the whales and porpoises; the appendages of some are clawed, others are hoofed, and others bear nails. These differences are used as the basis of third-rate categories known as *orders*. Man belongs to one of the 15 or 20 *orders* of the class Mammalia, called the order Primates.

The order Primates is divided into a number of smaller groups, such as the lemurs, the apes, several kinds of monkeys, and man. The name for the divisions of an order is *family*. Unfortunately the word family has two entirely different meanings. It is used in a social sense to mean a pair of individuals and their immediate offspring (*e.g.*, the John Smith family, or "a bluebird family"), and it is used among biologists to designate a category of lesser scope than an order, often embracing thousands of species, and millions of individuals. Thus, while the average social family comprises perhaps 4 or 5 individuals, the taxonomic *family*

Hominidæ embraces all men on the earth of whatsoever race or color, and includes, therefore, probably 1,750,000,000 individuals.

Two other categories of successively smaller scope than the family must also be understood; namely, the *genus* and the *species*. The family to which man belongs has only one genus, the genus Homo. Many families of animals have a number of genera, such as the deer family, which is known as the Family Cervidæ. The American elk is placed in the genus Cervus. The Virginia or white-tailed deer, the mule deer, and the black-tailed deer belong in the genus Odocoileus, the moose in the genus Alces, and the several kinds of Caribou in the genus Rangifer. *The family name is always formed by adding the letters idæ to the stem of the name of the typical genus.* Thus: Cervus, Cerv*idæ;* Homo, Homin*idæ;* Musca, Musc*idæ.*

The Species

The innumerable insects and other living things about us naturally group themselves into kinds or species, as every one knows who has said "Here is a new kind of flower," or "What kind of weed?" or "What kind of bird is this?" Not only do the progeny of a single pair associate together closely, but many other individuals of the same kind that look exactly like them, mingle with them, behaving in the same manner, eating the same kind of food, building nests that are very much alike, mating with each other, and continually bringing forth new individuals like themselves.

These natural kinds which normally associate in nature are known as *species.* We should recognize that a species is a *real group* just as truly as the individual animal or plant is real. To define species, however, is difficult. One important criterion is that the members of a species generally interbreed, the matings producing fertile offspring; while members of different species seldom interbreed, and if they do, the offspring are not fertile. One species differs from another by characteristics greater than the differences between the children of the same parents. These specific characteristics are constant from one generation to another and throughout the natural range occupied by that species. The species is the natural reproductive unit among animals.

It is not always easy to determine, among the hundreds of similar creatures occurring in any environment, where the limits of these natural reproductive units come. And to just so great a degree as we fail of determining this, our classification of animals is erroneous, incomplete, unsatisfactory, and subject to disagreement and dispute. Most of our classifying has unfortunately been done with dead and preserved specimens, and we rely upon the structural characters exhibited in these preserved specimens to point out the natural units of the living world. This has led some persons to the idea that species are mere subjective

conceptions, fashioned by the hand of man for his convenience in referring by a single name to a group of individuals that resemble each other in certain characteristics. But species do not originate in the cabinets of the museum worker or under the microscope, though the names of species may be originated there. Species are formed by the hand of nature, and many of them were present on the earth in remote times before systematic zoologists or botanists or entomologists came into being, just as truly as they are today, when systematists have discovered, named, and labeled over three-fourths of a million of them.

Because we often apply inadequate standards in recognizing species, and because resemblances which seem important to one naturalist may seem trivial to another, there are great differences of opinion about how many species exist. Too often we have classified insects according to their structure alone, and indeed very often according to the structure of only one part, or one set of organs. But if we are really to know the groups, as nature has developed them, we should study not only the structure of every part, but also their habits, mating, development, distribution, and perhaps even their psychology and fossil history.

Because of the great number of insects, the species is a fundamental conception without which little progress in economic entomology would be possible. If we had to cope with each *individual* insect as a separate problem, first determining its status as friend or enemy, and then working out a scheme of control for it, as determined by its structure and habits, our task would be utterly hopeless. But all of the individuals of a species *look alike, act alike, eat the same kind of food in the same manner, and are controllable in exactly the same way.* This is because, for the most part, insects lack initiative or intelligence. That is, they do not have the ability to profit by experience, but depend upon instinct, and do everything in the same way their ancestors have done for thousands of generations. All chinch bugs feed on grass plants, and fly to the same type of winter quarters, and crawl on foot from small grains to corn in early summer, and, if a barrier or trap is provided, they fall into it just as their ancestors have done ever since man has been trapping them. In the same way all boll weevils, all codling moths, all Colorado potato beetles, present one problem, and not a million different ones, although each species may be represented by millions of individuals.

Because of the great similarity of behavior these separate individuals do not require a name. But every *species* of insect about which we wish to write or speak must have a name. This may be a common name. In the past, common names have been applied by anyone who chose to apply them and without rules or regulations. Accordingly, the same kind of insect may have many different common names in different communities, and especially in different countries. Thus the corn earworm is known in different sections of this country as the tobacco budworm, cotton boll-

worm, tomato fruit worm and vetch worm. The squash bug is also commonly called pumpkin bug and stink bug. Furthermore the same common name is often applied to several very different kinds of insects. For example, the name *locust* in Biblical times, and at present in Europe, means a grasshopper, while to many of us it means a kind of cicada. Recently certain rules have been formulated for the application of common names of insects, and lists of names, approved by the American Association of Economic Entomologists, have been published.[1]

Dr. F. E. Lutz, in his delightful "Fieldbook of Insects," has termed the common names of insects "nicknames." He says:

> There are thousands of kinds of native-born, United States insects which have been really named but not nicknamed . . . Often real names are no longer or harder than the "common" names. An insect is considered to be christened when some student, who has found a kind which he thinks has never been named, publishes a description of it, and gives it a properly formed name. If somebody had previously named the same kind, *the prior name usually holds.*

It is evident that no sound progress could be made by using names as various and ambiguous as the nicknames of insects, because we could never be sure just what kind of insect was being considered by a speaker or writer. There is at least as much reason for insisting that each important species of insect pass under a single name as for objecting to the use of pseudonyms by our fellow men. This points to the necessity for *scientific names.* Scientific names are simply names applied under a set of rules and regulations to which the majority of systematic workers have agreed. Scientific names are written in Latin form since Latin is the most nearly universal language. And, being a dead language, its form is fixed and the scientific names are therefore the same in all countries and all languages. If these names seem a bit strange and difficult to use, we must nevertheless be willing to concede something to the necessity for exactness and uniformity, and to equal availability to all races. In the latter part of this book, the scientific name of each economic species discussed is given in a footnote.

By general agreement, the system called *binomial nomenclature* has become universal. By this system every species is given a name of two parts: the first part is the *genus* name, which is common to from one to many similar species in much the same way that our family names or surnames, such as Johnson or Andrews, are common to all members of the same social family; and the second part is the *species* name, which must never be given to more than one kind of insect in the same genus, in the same way that one family would not have more than one child with the same Christian name or given name, such as William or Richard.

[1] *Jour. Econ. Entomol*, Vol. 18, pp. 521–545, June, 1925; Vol. 19, pp. 797–799, October, 1926; and Vol. 20, pp. 837–839, December, 1927.

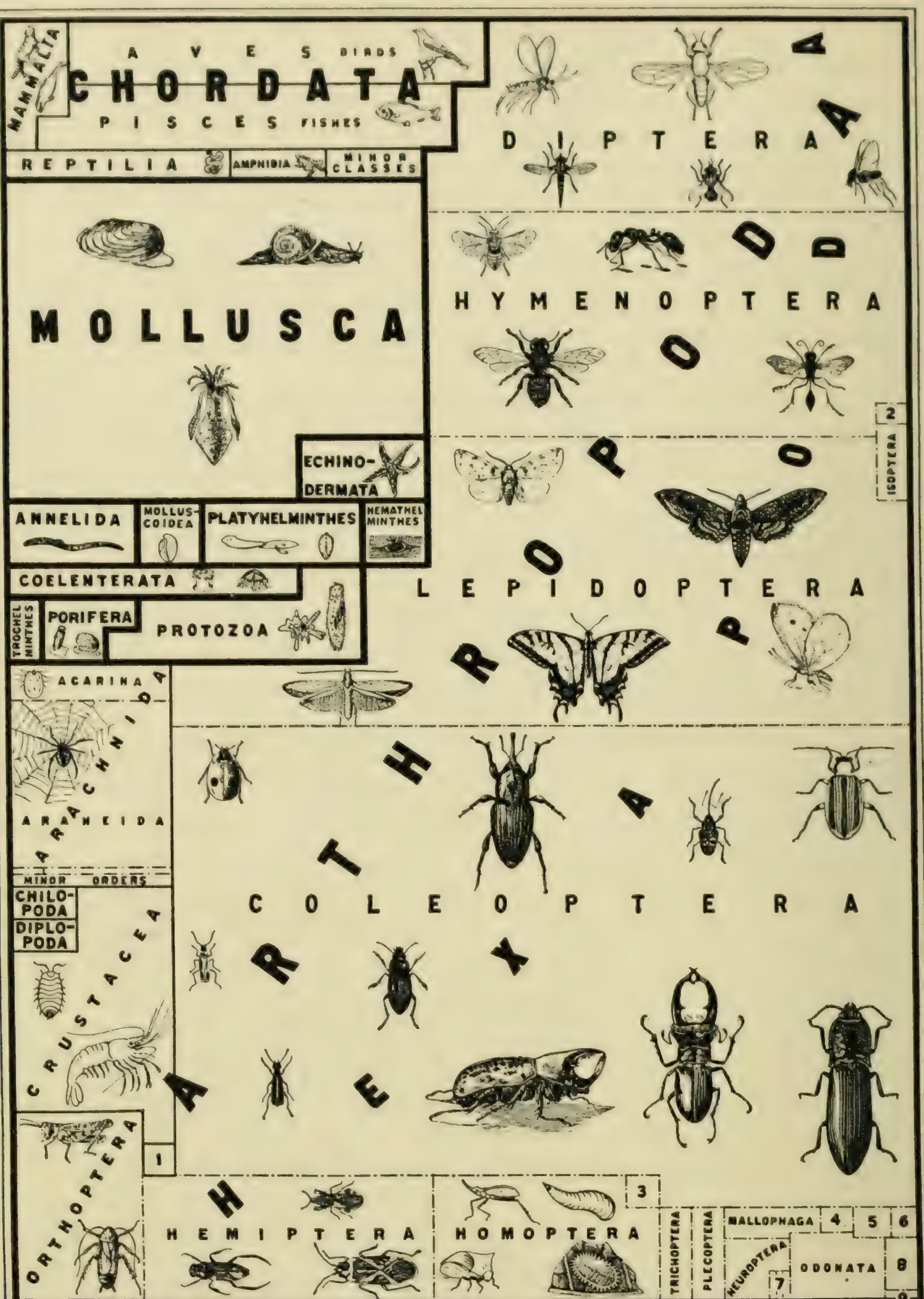

Fig. 86.—A diagram to show the relative size, in numbers of known species, of the various animal phyla, of the classes of two of these phyla (the Chordata and the Arthropoda), and of the orders of two of the classes (the Arachnida and the Hexapoda). Each square inch of this diagram represents about 30,000 known kinds of animals. The estimated number of species in each group is given in Tables IV, V, and VI, which should be studied in connection with this diagram.

The figure 1 represents minor classes of the Arthropoda; 2, the order Siphonaptera; 3, the order Corrodentia; 4, the order Ephemeroptera; 5, the order Dermaptera; 6, the order Thysanoptera; 7, the orders Anoplura, Strepsiptera and Mecoptera; 8, the order Collembola; and 9, the order Thysanura. (*Original.*)

By using a Christian name with a surname we designate each of our friends; by using the correct species name with the correct genus name, each insect kind may be clearly designated. A third part is usually added to the scientific name for convenience in finding the original description of the insect; that is, the name of the person, called the *author*, who first applied that particular name to the insect along with a published description of it. There are a few simple rules about scientific names that all should observe. The genus and species parts should always be printed in *italics* or, when written, should be underscored once. The author's name is not printed in italic letters or underlined. The genus part of the name comes first and is always written with an initial capital letter, the species part of the name is given second and should always begin with a small letter. The three parts of the name are written without any punctuation. Thus *Anasa tristis* DeGeer is the scientific name of the squash bug. This name tells us at once that the squash bug belongs in the genus *Anasa* and the species *tristis;* and further, that it was first named and described by DeGeer, who was a Swedish naturalist of the eighteenth century.

The various categories of successively smaller and smaller size, from the largest (the Animal Kingdom) to the smallest living unit (known as the individual), are given in the first column below. These are used somewhat like the divisions of the earth's surface, given in the last column below, in which each larger unit includes one to many smaller units. By way of illustration the complete classification of two animals, man and the house fly, are also given in parallel columns:

Kingdom	Animal	Animal	The Earth
Phylum	Chordata	Arthropoda	Hemispheres
Class	Mammalia	Hexapoda	Continents
Order	Primates	Diptera	Nations
Family	Hominidæ	Muscidæ	States
Genus	Homo	Musca	Counties
Species	sapiens	domestica	Townships
Variety	Caucasian		Sections
Individual	John Smith	Any house fly	Farms

The relation of the different categories to each other, and some conception of their relative size, may be gained by a study of Fig. 86. In this figure the heavy black lines mark off the *phyla* of animals. A definite area on the paper has been alloted to each group in proportion to the number of species known to scientists. The lighter, solid lines mark off the proportionate size of the *classes* of Chordata and Arthropoda; while the broken lines further subdivide the class Arachnida and the class Hexapoda into their named *orders*. It may be noted, for example, that the *order* Coleoptera is not only the largest order of animals, but is actually several times as large as the entire *phylum* Chordata or Mollusca.

The Phylum Arthropoda

In Chaps. III and IV, the important structural and functional characteristics of insects were described. No single one of these characteristics will define an insect and distinguish all insects from all other kinds of animals. For example, *the segmented body, bilateral symmetry, paired jointed appendages, chitinous exoskeleton, ventral nervous system, and dorsal heart* are the characteristics of the entire phylum Arthropoda, which includes besides the true insects, many other creatures such as crayfish, crabs, lobsters, sowbugs, centipedes, millipedes, spiders, mites, ticks, scorpions, harvestmen, and many others. The *phylum Arthropoda* is the largest phylum in the animal kingdom, and, aside from the vertebrates, the phylum of most importance to man. This phylum embraces five important and well-known classes, of which insects (the class Hexapoda) is one (see Table V). More than 75 per cent of all the animal

Table V.—The Phylum Arthropoda

Classes		*Examples*		*Estimated Number of Living Species Described*
Hexapoda (Insecta)		**All true insects**		**625,000**
Chilopoda		Centipedes or hundred-legged worms		1,000
Diplopoda		Millipedes or thousand-legged worms		1,000
Arachnida				
	Orders of the Class Arachnida			
	Scorpionida	Scorpions	600	
	Phalangida	Harvestmen or daddy-long-legs	2,000	
	Araneida	Spiders	15,500	
	Acarina	Mites and ticks	8,000	
	Minor Orders	Pseudoscorpions, whip scorpions	1,400	
		Total Arachnida		27,500
Crustacea		Crayfish, lobster, crab, sowbug, barnacles, water fleas, cyclops		20,000
Minor classes		Peripatus, king crab, Symphyla, Myrientomata		500
		Total		675,000

kinds hitherto found and named belong in the phylum Arthropoda and more than 90 per cent of these are true insects. The class Hexapoda is further analyzed in the following chapter, and, except for a number of references to mites and ticks, the remainder of this book is devoted to a discussion of important examples of insects.

The possession of three pairs of legs, three body regions, and wings are characteristic things that mark off the insects from the other Arthropods. Each of the other four classes is distinguished by certain structural features not possessed (at least in their entirety) by the rest of the

Arthropods. In common usage, many of the representatives of these other classes are considered to be "bugs" and the species of economic importance are dealt with chiefly by entomologists. Hence a brief discussion is given here of the classes Chilopoda, Diplopoda, Arachnida, and Crustacea (see also Table V).

Class Chilopoda: The Centipedes or Hundred-legged Worms (Fig. 87).—The closest relatives of the true insects are the centipedes. Like the insects, they have a single pair of antennæ, they breathe by tracheæ, and the reproductive organs open at the posterior end of the body. They

FIG. 87.—A giant centipede from the southeastern United States, feeding on a white grub. Note the size as compared with chair. (*Photograph from life by A. R. Cahn.*)

differ from insects in having neither thorax nor wings, and in the large number of legs, typically one pair to each body segment. They are wormlike in form, but differ from the true worms (*cf.* Fig. 45, *A*) in having a distinct head and definite jointed legs. They are usually somewhat flattened. There is a pair of poison claws or legs, on the first segment behind the head, that are used to paralyze insects and other prey that they devour. The centipedes may as a group probably be considered beneficial, although some of the species, especially the larger ones, which in the tropics may reach a length of 18 inches, sometimes inflict very painful bites upon man.

Class Diplopoda: The Millipedes or Thousand-legged Worms (Fig. 45, *D*).—Millipedes are superficially much like centipedes but differ in the following important respects. The legs are still more numerous than in the centipedes, each apparent body segment having two pairs of legs. The body is typically round in cross section, not flattened; there are no poison legs; the antennæ are short; and the reproductive organs open far forward close to the head. The millipedes generally feed on decaying vegetable matter, but some species attack growing crops in damp soil, eating either the roots, or the leaves that lie close to the ground. They are sometimes mistaken for wireworms and may be serious pests in fields and greenhouses. Many of the species have an offensive odor.

Class Arachnida: The Spiders, Ticks, and Their Relatives.—Next to the insects, the largest class of Arthropoda is the class Arachnida,[1] to which the spiders, scorpions, mites, ticks and harvestmen belong. The Arachnida resemble insects in their small size, in their predominately terrestrial habits, and in the possession of tracheæ. They differ radically, however, in having four pairs of legs; in having no antennæ, true jaws or compound eyes; in having only two body regions, the head and thorax being grown together into one region; in the curious "booklungs" used for respiration; in not having a conspicuous metamorphosis; and in the position of the openings from the reproductive organs which are near the front of the abdomen. There are a number of orders in this class of which the following need mention here.

Class Arachnida: Order Araneida.—This large order includes all of the spiders—a group of animals rivaling the snakes in their ability to frighten people. Comstock, the author of "The Spider Book," has well said: "Few groups of animals are more feared, and few deserve it less." All spiders have a pair of venomous jaws and live on insects which they poison with their bites. They can bite; and occasionally such bites may become infected and result seriously. But probably in all the world there are not more than a few species, if any, that are capable of killing man by their bites. Comstock assures us that there are no species in the northern United States that we need to fear. The large "tarantula" (Fig. 88) which comes into our midst in bunches of bananas, is capable of killing birds and small mammals by its bite. It apparently cannot kill a man, and besides, it seems hard to persuade it to bite a person. This has been shown by the experiments of Baerg in Arkansas.[2] Among our native spiders, the one having the worst reputation is the "hour-glass spider" or "black widow" (*Latrodectus mactans*) (Fig. 89).

[1] Care should be taken not to confuse the name of this class, Arachnida, with the name of the phylum, *Arthropoda*, since the names somewhat suggest each other to the beginner.

[2] *Annals Entomol. Soc. Am.*, Vol. 18, pp. 471–478, 1925.

Fig. 88.—Tarantula, about one-half natural size. (*From Herrick's "Insects Injurious to the Household." Copyright* 1914, *by The Macmillan Company, reprinted by permission.*)

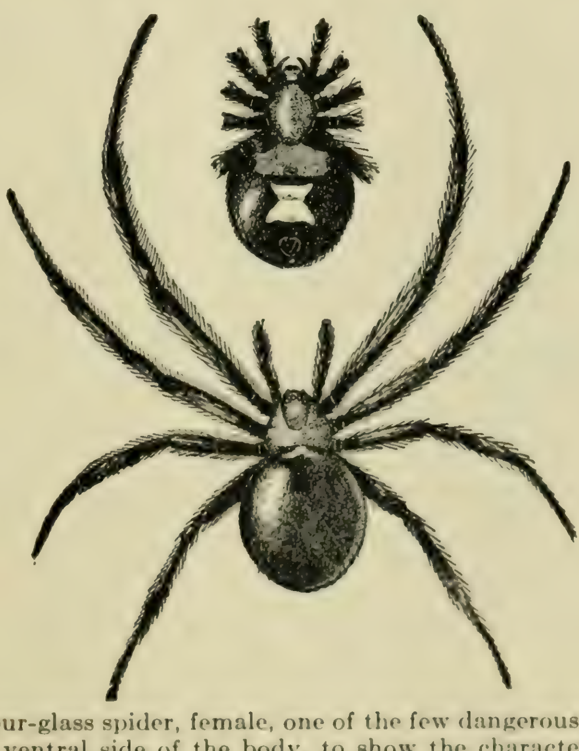

Fig. 89.—The hour-glass spider, female, one of the few dangerous spiders in the United States. Above, the ventral side of the body, to show the characteristic red, hour-glass-shaped spot. Below, dorsal view. Twice natural size. (*From Herrick's "Manual of Injurious Insects."*)

The female is about ½ inch long, bare, and coal black all over except for a curious, brick-red, hour-glass-shaped spot on the under side of the abdomen.

Not only are most spiders harmless to man, but, because of the insects they devour they are exceedingly beneficial. There are no species injurious to crops. But everywhere in the garden, the meadow, the fencerow, the orchard, or in buildings one finds them quietly sitting in wait. Who shall estimate the number of pests they devour before the latter have had opportunity to damage our plants or our animals? Anyone who can overcome his prejudices against these delightful little creatures, will find them most interesting entertainers. There are few better "shows" than to watch a spider spin her web, or to watch the elaborate courtship of the males. One is much impressed by the disadvantage in size which the male shows, for he is always much smaller. Someone has figured out that the disproportion would sometimes be equivalent to that between a man 6 feet tall and weighing 150 pounds, and a woman 90 feet tall and weighing 100 tons. And when one considers that her disposition often is to kill the male immediately after mating with him, one appreciates the poor chance male spiders have for a long life.

One of the most characteristic things about spiders is their habit of spinning silk. This is used in a variety of ways: (*a*) Chiefly it serves as a snare to capture food. It is quite a wonderful thing for a dumb animal to manufacture and set a trap. We know of none of the higher animals except man that do this, although it is done by some of the insects. (*b*) It forms tubes or tents for protection. (*c*) It forms sacs for protection of the eggs and newly hatched young. (*d*) It is used for locomotion. Spiders descend from higher to lower levels by spinning out a thread as they let themselves slowly down. Some spiders climb to a high point, and resting on their front legs begin to spin silk, supporting it by the hind legs until the loose end is caught by the breeze. More and more is thrown out until finally this simple kite exerts pull enough to carry the spider away. This can usually be observed in the open country on any bright autumn day.

Class Arachnida: Order Acarina (Fig. 90).—Mites and ticks can usually be told at a glance from spiders or insects, because the body is all one region, there being little indication of either body regions or segments. They are like the spiders in the matter of appendages, and some of them spin silk. A curious feature is that the newly hatched young have only three pairs of legs. They breathe either by tracheæ or directly through the skin. The only difference between mites and ticks is a difference in size; that is, the larger members of this order (Fig. 90, *A*) are called *ticks*, while the smaller ones (*B*) are called *mites*.

The economic importance of the mites and ticks is at least fourfold: (*a*) Some of them injure plants. For example; the red spiders and the gall

mites. (*b*) A number of species are found on or in the bodies of insects. Some of them are said simply to be riding upon the insects to a new feeding ground, but at least some species are parasitic upon the insects. Thus the Isle-of-Wight disease among honeybees is caused by a kind of

FIG. 90.—A tick, the spotted-fever tick (*from Cooley*) and one of the smaller members of the same order, usually called a mite, the tropical fowl mite. Much enlarged. (*From Cleveland*).

mite that lives in the tracheæ of the bee. (*c*) Many species are parasitic upon other animals, including man. Here the most notorious examples are the cattle tick, the Rocky Mountain spotted-fever tick, the poultry mite, itch mite, scab mite, and scaly-leg mite. (*d*) Many of the parasitic species are to be feared because they are the known and only carriers of some animal diseases. Thus Texas fever is transmitted only by the bite of the cattle tick, Rocky Mountain fever of man only by the spotted-fever tick, and fowl spirochætosis by the fowl tick (see also Table I, pp. 24, 25). The important species of Acarina are further discussed in the following chapters, in connection with the crops and animals they injure.

FIG. 91.—A pair of scorpions in the attitudes assumed during courtship. About natural size. (*From Fabre.*)

Class Arachnida: Order Scorpionida (Fig. 91).—The scorpions are common in the southwestern part of the United States and other subtropical and tropical regions. They are well known at least by name to nearly everyone, because of their reputation as stingers. The sting is borne at the tip of the abdomen. The latter is unusually long, and the terminal half of it much more slender than the basal half. In addition to the four pairs of walking legs, scorpions have the pedipalps developed to very large size, and provided with a pair of pinchers so that they appear to have five pairs of legs. The pedipalps

are used to grasp prey and the abdomen is then curled forward over the back and the stinger plunged into the victim to paralyze it.

The young are born after hatching from the eggs, and they are said to be carried about by the mother for a time after birth, clinging with their

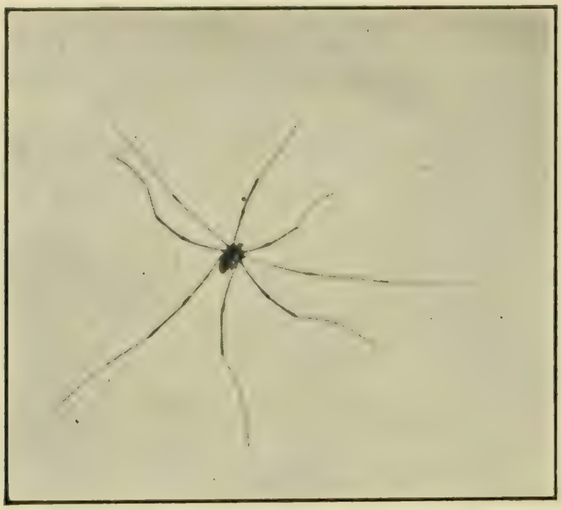

FIG. 92.—A harvestman or daddy-long-legs. Natural size. (*From Slingerland.*)

pinchers to her body. They are nocturnal creatures that forage about at night, catching and stinging spiders and insects. They may probably be

FIG. 93.—A crayfish about natural size. (*From Fernald's "Applied Entomology."*)

considered a beneficial group. Their sting, although capable of causing a painful wound to man, is probably never fatal.

Class Arachnida: Order Phalangida (Fig. 92).—The harvestmen or daddy-long-legs are familiar to all out-of-door persons. They look much

like very long-legged spiders, but close examination will show that the body is not divided by a slender waist. The legs are carried with the "knees" high, and the body swung low between them. The creatures have a noticeable odor that probably discourages many enemies, and Comstock suggests that the ease with which the legs separate from the body is a protective adaptation, enabling them to get away from predators that grasp them by a leg—minus that leg!

The food of the harvestmen is not well known. Some authors state that they feed largely upon insects, others that they take only dead insects and soft fruits and other plant tissues. At any rate they are not known to have any injurious or objectionable habits.

Class Crustacea: The Crayfish, Crabs, Sowbugs, and Their Relatives (Figs. 93 and 94).—The crayfish, lobsters, and crabs are the largest and

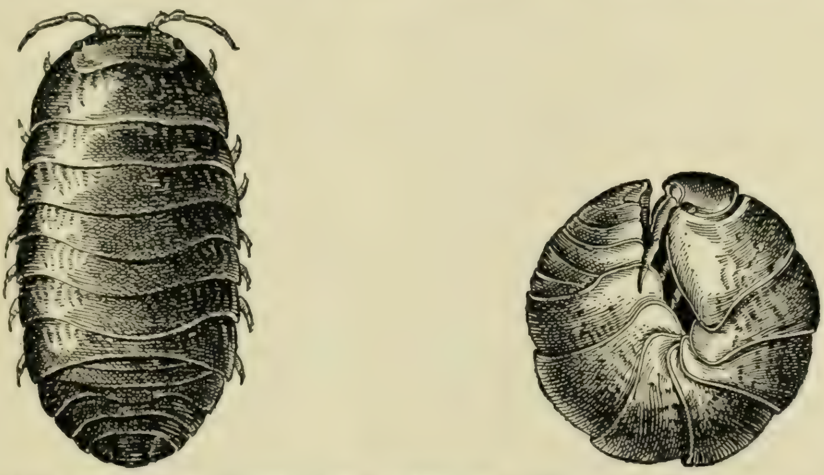

Fig. 94.—The greenhouse pillbug. Left, extended; right, rolled into a ball. Enlarged (*From U. S. D. A. Farmers' Bull.* 1362.)

best known representatives of this class. They are farthest removed from the insects of any of the classes of Arthropods discussed in this book. They have five pairs of walking legs, paired jointed appendages on the abdomen, two pairs of antennæ, and only two body regions. Unlike insects they have no tracheæ and breathe by blood gills or through the skin. The forms most likely to be confused with insects are the small terrestrial sowbugs and pillbugs which abound under boards, logs, in greenhouses, and other damp places. The pillbugs have the habit of rolling themselves into a nearly perfect sphere when disturbed. They are sometimes injurious in greenhouses.

In this chapter we have seen that all the insects constitute one class (the class Hexapoda) of one of the phyla (the phylum Arthropoda) of the animal kingdom. We have also seen what are their general relationships to the other important classes of this phylum. In the following chapter a third step in classification, the division of the insect class into its orders, is explained.

CHAPTER VIII

THE ORDERS OF INSECTS

In the preceding chapter, the place of insects in the animal kingdom was discussed and it was pointed out that the insects constitute the largest of all animal groups. Indeed, about 75 per cent of all the known kinds of living animals are insects. In spite of their great numbers, insects have so many important characteristics in common that they are all included in one class, the class Hexapoda. Between 600,000 and 700,000 different kinds have been discovered, properly named, and described. Thousands of new kinds are being found every year, indicating that we are far from having reached a full knowledge of this class. The number of kinds that are probably living in all parts of the earth according to Gossard[1]

> . . . is variously estimated at from 2,500,000 to 10,000,000, with the probabilities favoring the latter figure as the more nearly correct. Assuming the maximum figure to be correct, in what a field does the entomologist find himself! Suppose that he attempts to familiarize himself with each species so that he will recognize it the next time he sees it. Since his task is obviously great, we will start him at it at the age of 5 years and allot him 5 minutes in which to study each species, giving him one-half of the time to a male specimen and one-half to a female. Lest he should become lazy, we will provide him with electric lights and keep him working day and night and lest he should become fat, we will forbid him to eat except as he is able to snatch mouthfuls from the 5-minute intervals during which he is expected to fix in his memory the anatomical characters, color patterns, etc., which differentiate each species from every kindred one. Working in this manner and at this rate, the rains of nearly 100 summers will have fallen on his roof before the last representative of the long procession of insects has passed before him.

Obviously none of us shall ever learn to know all of the kinds of insects! Obviously, too, no one need be surprised if an entomologist cannot tell him, offhand, the name of every insect encountered. The field is so vast that it is, in its finer aspects, beyond the comprehension of any one man.

A good working knowledge of the groups of insects, however, is within the grasp of any earnest student. The largest groups of insects are known as *orders*. About 25 orders are commonly recognized by entomologists. Some of these contain only a few species which are so rare as to be almost never encountered. A number of others contain many species common and interesting but of no great importance to man. In the following table (Table VI) are listed 23 orders, and from these are selected for

[1] Gossard, H. A., *Jour. Econ. Entomol.*, Vol. 2, p. 314, October, 1909.

TABLE VI.—THE ORDERS OF THE CLASS HEXAPODA

Types of Mouth Parts	*Orders*[1]	*Examples*	*Estimated Number of Species Described*	*Number of Wings in Adult*
		Insects without Metamorphosis *Primitively Wingless Insects*		
Chewing in nymphs and in adults	**Thysanura**	Bristletails, silverfish	300	No wings
	Collembola	Springtails, snow fleas	1,200	
		Insects with a Gradual or Simple Metamorphosis *Wings Develop Externally on Nymphs. Nymphs have Compound Eyes*		
	Orthoptera	Roaches, crickets, grasshoppers, katydid, walking-sticks	18,000	Four wings (rarely none)
	Dermaptera	Earwigs	900	
	Ephemeroptera	May-flies, shad-flies	800	
	Odonata	Dragonflies, damselflies	5,000	
	Plecoptera	Stone-flies, salmon-flies	2,000	
	Isoptera	Termites, "white ants"	2,000	Four wings or none
	Corrodentia	Book lice, bark lice	750	
	Mallophaga	Chewing lice, bird lice	2,100	No wings
Rasping-sucking (transitional?) in nymphs and in adults	**Thysanoptera**	Thrips	600	Four wings or none
Piercing-sucking in nymphs and in adults	**Homoptera**	Aphids, scale insects, cicadas, leafhoppers	25,000	
	Hemiptera	Chinch bug, squash bug, bedbug, stink bugs, leaf bugs, aquatic bugs	30,000	
	Anoplura	Blood-sucking lice, "cootie," hog louse, cattle lice	150	No wings
		Insects with a Complete or Complex Metamorphosis *Wings Develop Internally in Larvæ. Larvæ do not have Compound Eyes*		
Chewing in larvæ and in adults	**Coleoptera**	Beetles, weevils	250,000	Four wings (rarely none)
	Strepsiptera	Twisted-wing parasites	150	
	Neuroptera	Aphid-lions, ant-lions, dobson flies	2,500	
	Mecoptera	Scorpion-flies	150	
	Trichoptera	Caddice-flies	2,000	
Chewing in larvæ; siphoning in adults	**Lepidoptera**	Butterflies, moths, skippers	120,000	
Chewing or reduced in larvæ; chewing or chewing-lapping in adults	**Hymenoptera**	Bees, wasps, ants, sawflies	86,000	Four wings or none
Chewing in larvæ; piercing-sucking in adults	**Siphonaptera**	Fleas	400	No wings
Chewing or reduced in larvæ; piercing-sucking or sponging in adults	**Diptera**	Flies, mosquitoes, gnats, sheep "tick"	75,000	Two wings or none
Total	23 orders[1]		625,000	

[1] The orders *Protura*, *Zoraptera* and *Embioptera* are also recognized by many recent writers. They are omitted from this table because the species are so rare that they are not likely ever to be seen by the readers of this book.

special study 13 orders which contain species of importance to man, and these are printed in **black face type**.

ORDER THYSANURA

The Bristletails, or Silverfish

This is one of the smallest orders in number of known species, but it is included here for two reasons. It contains a few species known as silverfish, fish moths, slickers, or firebrats that are great household pests. These are further discussed in the chapter on Household Insects (see p. 744) and it need be said here only that these carrot-shaped, swift-running nocturnal pests (Fig. 95) are often injurious to stores of paper stock, book bindings or lettering, card labels or indices, wall paper, and similar starched or sized articles which they eat. Another reason for placing the Thysanura in the list for special study is that they may represent a very lowly offshoot from the insect family tree. Together with the Collembola, they make a group, called the *primitively wingless insects*, which are very different in structure and metamorphosis from the higher insects. Many insects such as fleas, lice, some ants, and aphids are wingless throughout all the stages of their life. Study has shown that the kinds just named are wingless by specialization or degeneration. The members of the order Thysanura, however, are believed to be insects that never had wings in their ancestry, having branched off from the insect stock before the latter evolved wings.

Fig. 95.—A common household silverfish (*Thermobia domestica* Packard), a little larger than natural size. (*From Kellogg's "American Insects," after Howard and Marlatt.*)

Because of the absence of wings in the Thysanura, they may be said to have no metamorphosis. The young, also called nymphs, grow gradually toward the adult condition without any appreciable change in form or appearance except the change in size (Fig. 78). The mouth parts are of the chewing type, sometimes curiously set into the head cavity so that only the tips of the parts project from the surface. Compound eyes are present in some species, degenerate in others and wanting in some. The antennæ are long and many jointed and most species have at the tail end of the body two or three bristle-like, many-jointed appendages something like antennæ, from which the common name is given. Some of the species have leglike structures on the segments of the abdomen, a condition unique among insects. The body is very soft, but is covered with scales or hairs, which give it a shiny appearance and also account for the

name fish-moths. Thysanura live a hidden life, being found in cracks and crevices about buildings, under stones, and in the soil among leaf mold. When disturbed they scuttle about with great rapidity. Most of the species are thought to be scavengers.

Primitively wingless insects. Mouth parts chewing. Abdomen of 10 *or* 11 *segments. Antennæ very long, many-segmented. A pair of long cerci at the posterior end and sometimes three such antenna-like tails. Sometimes rudimentary legs on the abdominal segments. No metamorphosis.*

ORDER COLLEMBOLA

The Springtails and Snow Fleas

The springtails are small-to-minute insects, often occurring in enormous numbers on the surface and in the soil of woodlands, in decaying vegetable matter, on the surface of stagnant water, or on snow and other damp places. They are seldom noticed except by those who seek them. The points of principal interest about them are that they are entirely and primitively wingless, that they have a forked muscular appendage at the tip of the abdomen which is used in springing into the air (Fig. 96), and that they occasionally become pests about maple-sap buckets, in mushroom beds, or on seedlings in greenhouses.

Fig. 96.—The spotted springtail (*Papirius maculosus* Schött) about six times natural size. Note the adhesive tube between first and second pairs of legs, and the extended spring behind. (*From Kellogg's "American Insects."*)

Primitively wingless insects. Mouth parts chewing; sunken into the head. Malpighian tubes wanting and the tracheal system very slightly developed. Never more than six abdominal segments, the first with forked adhesive organ or ventral tube, shown between the first and second pairs of legs in the figure, and the fourth with a forked spring. Antennæ of few segments. Development without a metamorphosis.

ORDER ORTHOPTERA

Grasshoppers, Crickets, Katydids, and Others

This large order includes some very primitive insects, such as the roaches; some that are well known to everyone, like katydids and crickets; and some that are very destructive to crops, like grasshoppers. They are mostly large insects, and many of the species make sounds, so that they attract a great deal of attention. The groups that make noises have the hind legs unusually long and powerful, and progress by jumping. The sounds are not voices. They do not come from the mouth, but are produced by rubbing rough surfaces of the body together. In the crickets and katydids, specialized parts of the front wings are rubbed together to make the sounds. In some grasshoppers the front and hind wings are rubbed together; others rub the inner surface of the hind leg (the femur) over the outer edge of the front wing. It is the males that produce these sounds, the females almost never having special organs for this purpose.

Both sexes, however, commonly have sound-perceiving organs or "ears" (see p. 98).

All of the Orthoptera have well-developed chewing mouth parts. Many kinds feed on plants, others on small animals, and still others are scavengers. The metamorphosis is a gradual one, the nymphs generally passing through five instars. Most species live exposed on plants or hidden on the surface of the ground, but a few burrow into the soil and a very few take to the water. The wings when present are four in number, the front pair narrow and thickened, but with the veins showing, and capable of bending without breaking, somewhat like a piece of leather. The hind wings are thin; often brightly colored and with many veins; broadly triangular, and, when brought to rest, they fold along radiating straight lines from the base, like a fan, and are laid back over the abdomen, so that they are covered by the front wings (see Fig. 219). The antennæ are generally long and prominent, the legs are long, the prothorax is large, and the tip of the abdomen is provided with a pair of cerci and often with a prominent ovipositor in the female (Fig. 97). Here belong some of the largest of all insects, a Venezuelan grasshopper that measures $6\frac{1}{2}$ inches in length, and African walking sticks 10 inches long. In temperate latitudes most species spend the winter in the egg stage.

FIG. 97.—A common short-winged cricket, *Gryllus assimilis* (Fab.), female. Note the long, spear-shaped ovipositor and, just above its base, the two cerci. (*From Kellogg's "American Insects."*)

Mouth parts chewing. Wings four, sometimes greatly reduced or wanting. The front pair narrow, somewhat thickened but distinctly veined. The hind pair membranous, broad, and folded fanlike when at rest. Cerci and an ovipositor generally present. Metamorphosis gradual.

Important economic species of this order are grasshoppers(pp. 327; and 441), tree crickets (p. 637), and roaches (p. 742).

The Families of Orthoptera

The families of Orthoptera are so distinct that certain writers have proposed separate orders for some of them. The first three families discussed have been called the singing, jumping Orthoptera (Saltatoria), since most of the males have stridulating organs, and all have the hind legs noticeably longer and stouter than the others. In the females the ovipositor is usually well developed. The tarsi have fewer than five segments in these three families.

Family Locustidæ (also called Acrididæ). The Grasshoppers or Locusts (see Figs. 216 to 219). These are moderately long insects, a little flattened from side to side, with prominent heads and large eyes, all characteristically active in the daytime. The antennæ are always much shorter than the body, the tarsi have three segments, and

the "ears" (see Fig. 46) are found on the sides of the first abdominal segment. The ovipositor consists of four short, finger-like pieces, well separated (Fig. 46). These are used to thrust the eggs into the soil or into soft wood, ½ inch or 1 inch below the surface (Fig. 216). The eggs are formed into definite masses of 20 or more each, and are surrounded by a frothy, gummy substance which hardens to form a protective case for them. There is usually only one generation a year.

Family Tettigoniidæ (also called Locustidæ). The Long-horned Grasshoppers, Green Meadow Grasshoppers, Katydids (Fig. 98), *Cave and Camel Crickets.*—These are more delicate and less hardy insects than the true grasshoppers, but of somewhat similar form. They are often nocturnal, and can be distinguished from the grasshoppers by their very long antennæ, often longer than the body, and by having four segments in each tarsus. The "ears" are on the base of the front tibiæ (see Fig. 47, *A*) and the ovipositor is *sword-shaped*, the four pieces being flattened and closely appressed. The eggs are laid singly or in rows often on or in leaves, stems, or twigs, but some lay them in the soil. There is only one generation a year. As a rule they eat either plants or small animals. Only a few of them are serious pests.

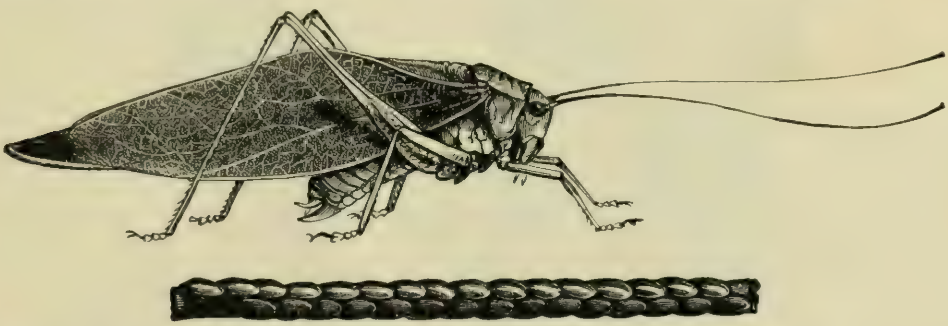

FIG. 98.—The angular-winged katydid, *Microcentrum laurifolium* (Linn.), and its eggs. Natural size. (*From Sanderson and Jackson, "Elementary Entomology," after Riley.*)

Family Gryllidæ. Crickets (Fig. 97), *Tree Crickets* (see Fig. 432), *Mole Crickets.*—These are usually somewhat short, dark-colored Orthoptera with the tarsi three-segmented like the grasshoppers, but the antennæ very long. In those kinds that have wings and produce sounds, the "ears" are found on the front tibiæ (Fig. 47, *A*). The ovipositor is a long, *spear-shaped* tube. The front margin of the wings is bent sharply down over the sides of the abdomen, like the edge of a box lid. The eggs are laid in groups in the soil or inserted into the stems of plants.

Crickets are nocturnal and negative to light, and feed upon a great variety of substances. The tree crickets are slender greenish kinds that live among tall weeds, trees, or bushes, and sometimes cause damage by slitting twigs and depositing their eggs in them (see Fig. 5, *B*). A curious fact is that the male has glands opening on the upper side of the thorax from which the female feeds at the time of mating. The mole crickets often burrow and make nests in the soil in the vicinity of water. They eat plant roots, other insects, and earthworms. The body is covered with fine, brown, velvety hairs and the front legs (Fig. 47, *A*) are remarkably developed, both for digging and to act like a pair of scissors, which some investigators think, are used to cut off small roots that are in their way. The ordinary black field crickets and the "cricket of the hearth" are other well-known representatives of this family. Crickets often do damage in grain fields by cutting the twine used to bind sheaves.

The last three families of Orthoptera have been called the mute, non-jumping Orthoptera, since they make no particular sounds and do not have the hind legs enlarged for leaping. The tarsi are always five-segmented in these families and the ovipositor is concealed or wanting.

Family Phasmidæ. Walking Sticks, Walking Leaves, Devil's Darning Needles (Fig. 99).—Our common representatives of this family are extremely elongate, cylindrical, wingless, with long stiff legs and very long, slender antennæ. They are found feeding upon the foliage of trees, but also often resting about buildings. They move but little and in a very stealthy manner, and are doubtless often overlooked by their enemies because they look so much like slender sticks, being good examples of the phenomenon known as *protective resemblance.* The eggs are simply dropped by the females, one at a time, as they rest among trees, and have often been said to make a noise like the patter of rain drops, when the insects are abundant. They are harmless to man except that they may injure trees by eating the leaves.

Fig. 99.—A walking stick in its usual environment among leaves and twigs. The head is just above the center of the picture, with the long front legs projecting straight forward toward the upper right. (*From Slingerland.*)

Family Blattidæ. The Roaches or Cockroaches (see Fig. 499).—This family has been called the running Orthoptera. The body is flattened, the head is bent downward and backward and is not prominent. The prothorax is very large, the legs are long and bristly, the hind pair only moderately larger than the others, but the coxæ are all very large. The wings may be well developed, short, or wanting; they lie flat over the back, crossing over somewhat toward the tip.

Cockroaches usually have a bad odor, and they frequent all sorts of filthy places and dusty crevices, so that they are inexpressibly dirty. They are common in kitchens, bakeries, and restaurants, and may be carriers of disease germs. The eggs are formed into packets, enclosed in seedlike cases, and these so-called oöthecæ are often carried about by the female partly extruded from the abdomen until the nymphs hatch from them (see Fig. 499, *f*)

Cockroaches are very sensitive to cold. Many species live out-of-doors, and in moist tropical countries are very abundant. Four or five species have the habit of living in dwellings and other buildings. These will be further considered under the discussion of household insects.

Family Mantidæ. Praying Mantes, "Mule Killers" (Fig. 100).—These remarkable creatures have curious habits and odd structures. The common name comes

from the manner in which they hold up the front end of the body, with its enormous front legs, as though in an attitude of prayer. They might also be called *preying* mantes, for they are the only family of Orthoptera that seems to be exclusively carnivorous, eating other insects.

The body is elongate, the prothorax and fore coxæ especially long, and the front legs so modified that they can grasp small insects between the spiny tibiæ and femora, the former closing against the latter like a knife blade against its handle (see Fig. 47, *G*). The wings are usually well developed, but the mantes commonly remain quiet in one place until some insect comes within reach. They sometimes cautiously stalk their prey. The eggs are laid in large masses an inch or so long in a frothy, gummy substance, on the twigs of trees. These ferocious but beneficial insects are not commonly found north of the 40° of latitude. They never hurt man or the large animals. Some tropical species of this family are very broad and have the fore wings so modified as to resemble leaves, both in shape, color and venation.

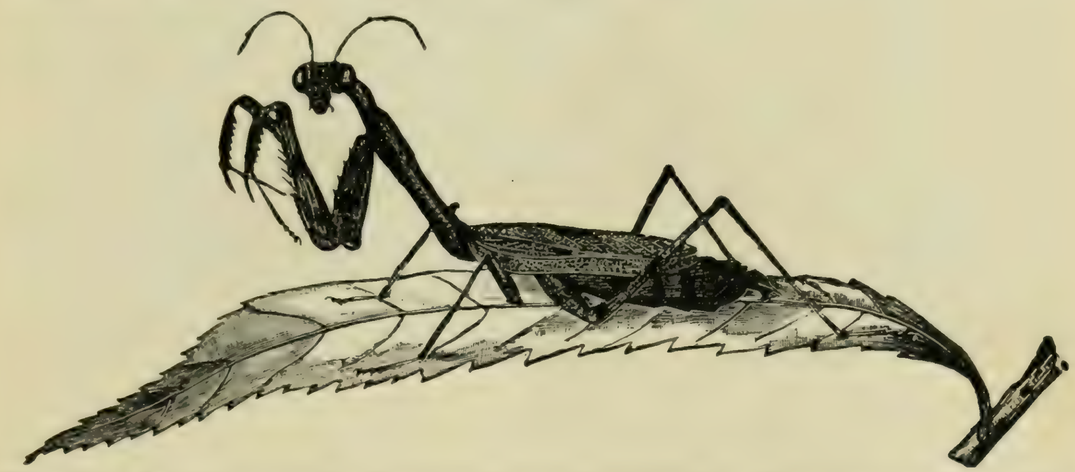

Fig. 100.—A praying mantis, *Stagmomantis carolina* (Linné). About natural size. (*From Comstock's "Introduction to Entomology," Comstock Publishing Co.*)

ORDER DERMAPTERA

The Earwigs

The earwigs are beetle-like insects easily distinguished from the Coleoptera by the prominent forceps at the rear end of the body and by their gradual metamorphosis. The mother broods over her nest of eggs in the soil and guards the young nymphs (Fig. 101). The food is variable, some species attacking plants in an injurious manner, others catching insects, and others feeding on decaying matter. Sometimes they become serious pests in and about houses, although the superstition that they attack people in the ears is absurd.

Front wings beetle-like, meeting in the middorsal line, but very much shorter than the abdomen. Hind wings membranous, ear shaped, the veins radiating from the middle of the costal margin. Often wingless. A conspicuous pair of hooks or forceps at the end of the abdomen. Mouth parts of the chewing type. Metamorphosis gradual.

ORDER EPHEMEROPTERA (EPHEMERIDA)

The May-flies, Lake-flies, or Shad-flies

These delicate, defenseless creatures (Fig. 102) often appear in surprising numbers in cities near lakes or streams, being strongly attracted by lights. They live but a few hours or a few days as adults, but this is often preceeded by one, two or three years of life beneath the water as nymphs.

The nymphs (Fig. 102, *B*) feed mostly on living or dead aquatic vegetation and breathe through tracheal gills. They are important as food for fishes. The adults take no food, but are frequently a nuisance because their dead bodies accumulate in windrows on streets and about watering places and smell bad.

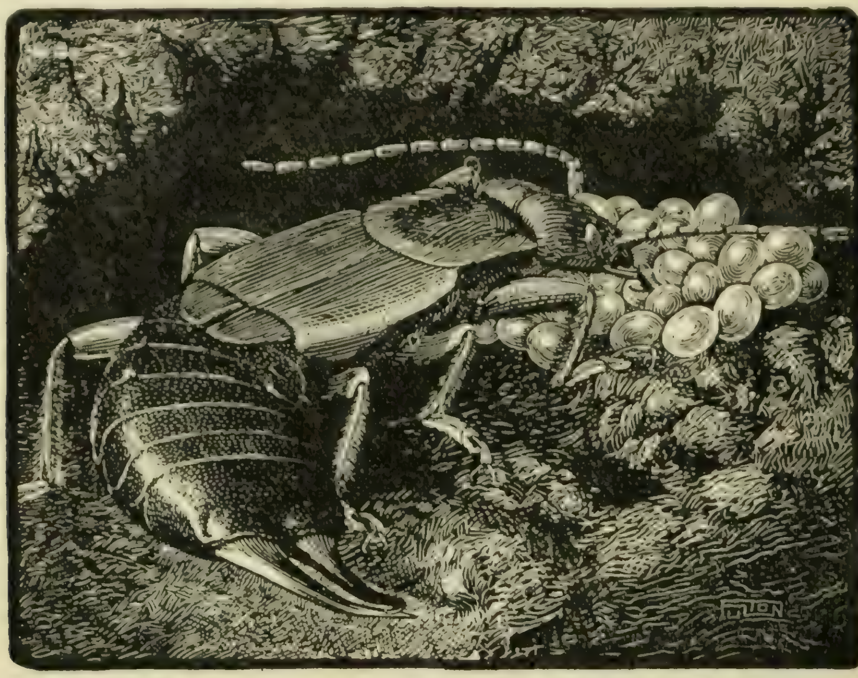

FIG. 101.—A female earwig brooding over her nest of eggs. (*From Fulton, Ore. Agr. Exp. Sta. Bull.* 207.)

Slightly chitinized adults, living but a short time, and molting once after reaching the winged, adult stage. Four, net-veined, gauzy wings, folding vertically over the back, when at rest; the hind pair much smaller, rarely wanting. Mouth parts of chewing type, but degenerate or wanting in adults. Antennæ very short. Two or three, very long, slender,

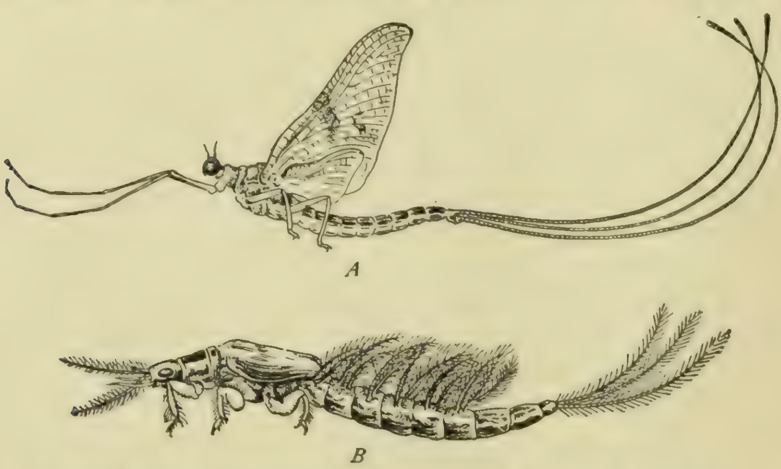

FIG. 102.—A May-fly (*Ephemera varia* Eaton). *A*, the adult; *B*, the nymph, about natural size. Note the tracheal gills on abdomen of the nymph. (*From Comstock, after Needham, Comstock Publishing Company.*)

many-jointed "tails." Genital openings double. Metamorphosis gradual, the nymphs aquatic, elongate; the abdomen with two or three slender tails and seven (or fewer) pairs of tracheal gills along the sides and on the back of the abdomen. A single claw on each nymphal tarsus.

ORDER ODONATA

The Dragonflies (Fig. 103) and Damselflies

The adults are aerial; expert flyers; abounding about ponds and streams; catching and eating other insects on the wing (see p. 54). The nymphs (Fig. 103, *1*, *2*, *3*) are aquatic, walking or hiding on the bottom of ponds and streams and catching other small animals for food. The development of a generation generally requires about a year, but some require several years. Odonata are of value to man by their feeding on horseflies and mosquitoes and as food for fish.

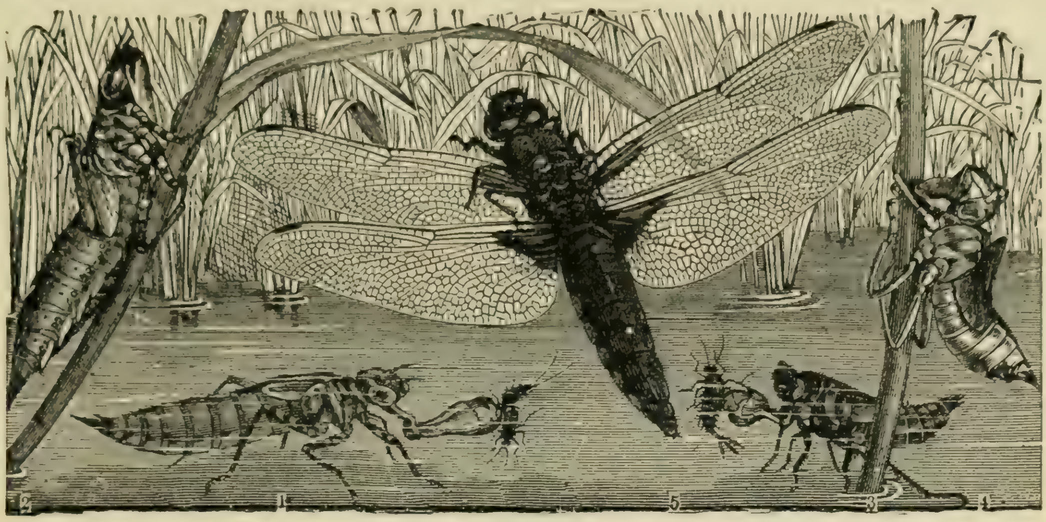

Fig. 103.—A dragonfly, adult and nymphs. At 1 and 3 two nymphs are shown catching prey with the extended labium. 2 is a mature nymph ready to change to the adult. 4 is the shed skin (exuviæ) from which the adult (5) has emerged. (*From Sanderson and Jackson, after Brehm.*)

Chewing mouth parts. Four membranous, slender, finely net-veined wings of about equal size; near the middle of the front margin is a short, heavy cross-vein and a slight notch, like a joint; and near the tip of the front wings a dark stigma. Antennæ very small. Compound eyes large. Abdomen very long and slender. Copulatory organs of male on the second abdominal segment, separate from the openings of the vasa deferentia. Metamorphosis gradual, the nymphs developing in the water and being provided with a very long labium, used in capturing prey, and folding like a mask over the face when not in use (Fig. 103, *1*, *cf. 4*).

There are two suborders differing as follows:

The Anisoptera or Dragonflies	*The Zygoptera or Damselflies*
Hind wings broader at base, not folded but held in a horizontal position at sides of body when at rest. Strong flyers.	Two pairs of wings of same size and shape, narrow at base; folded back over the abdomen or up over the back, like those of a butterfly, when at rest. Feeble flyers.
Eyes do not project from the side of the head.	Eyes projecting, constricted at the base.
Eggs laid on the water or on aquatic plants.	Eggs thrust into the stems of aquatic plants.
Nymphs breathe through tracheal gills inside of the rectum, and the forcible ejection of water from the anus propels the nymphs forward.	Nymphs breathe by three leaf-like tracheal gills, projecting from the end of the abdomen.

ORDER PLECOPTERA

Stone-flies

These retiring insects are seldom seen except by those who seek them. They live near streams, resting on stones, trees, and bushes, or flying over the water. Some species are not attracted to lights. The adults (Fig. 104) have rather long antennæ, but the tail-like cerci are much shorter than in the May-flies; and the hind wings are much broader than the front pair. The wings fold flat over the back, giving the insects a straight-sided, square-shouldered appearance when resting. The nymphs develop in the water, being common on the upper sides of stones in swift streams.

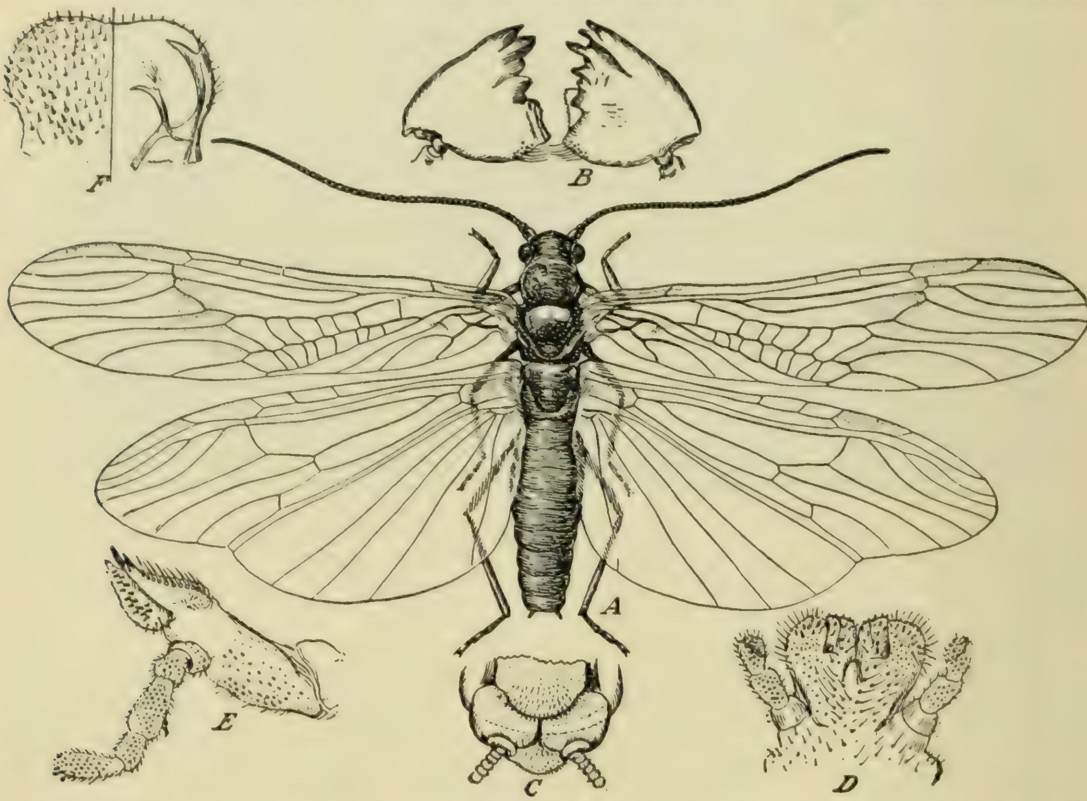

Fig. 104.—A stone-fly, *Tæniopteryx pacifica* Banks, much enlarged. *A*, dorsal view of adult about four times natural size; *B*, mandibles; *C*, last segment of female from below; *D*, labium; *E*, maxilla; *F*, labrum, dorsal half at left, ventral half (epipharynx) at right. (*From Newcomer, in Journal Agric. Research, Vol.* XIII.)

They feed mostly on diatoms, algæ, and other small plant and animal forms. In contrast with May-fly nymphs, they usually bear their gills on the thorax and have two claws on each leg (Fig. 79, *A*). Their only importance to man is as food for fishes.

Wings four, netted veined; front pair narrow, hind pair very broad, folding like a fan; abdomen thinly chitinized. Mouth parts of the chewing type but often reduced. Metamorphosis gradual.

ORDER ISOPTERA

Termites or "White Ants" (Fig. 105)

These are the yellowish-white, soft-bodied "wood ants" that we see so often in countless numbers in logs or stumps or in timbers of buildings or in wood lying in contact with the soil. They are not ants

at all, being very different from ants in structure and in metamorphosis. One easy way to distinguish them from ants (see order Hymenoptera) is to note that the base of the abdomen is broadly joined to the thorax and not by a slender petiole.

Their chief resemblance to ants is in their colonial or social life. This is a curious condition, found in this order and in some of the Hymenoptera, in which only a few of the many individuals become parents, all the others devoting themselves to the care of the thousands of offspring from the few "kings" and "queens." These kings and queens are not rulers in any sense, but simply reproductive individuals that do not even feed themselves. In the termites, in contrast with the ants, bees, and wasps, the males live a long time and mate repeatedly with the queens, and all termite eggs are fertilized. Some of them develop into kings and queens, which are dark in color and which have four, similar,

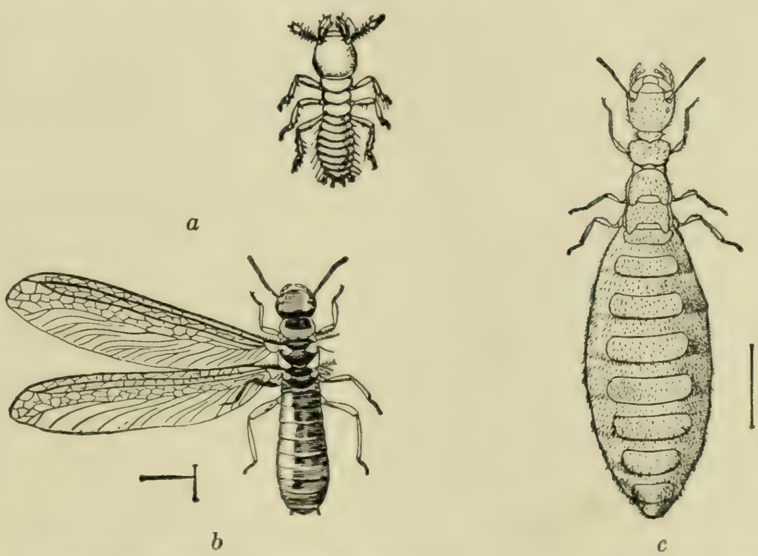

Fig. 105.—A common North American termite. Above at left a worker; below a male with right wings removed; at right a queen after she has lost her wings and her eggs have developed, distending the abdomen. Note the thick waisted condition of all. (*From Kellogg's "American Insects."*)

long, narrow wings with many indistinct veins (see Fig. 496). These wings are used only for a single flight, after which the wings are broken off along a suture of weakness near the base, and then pairing, and, subsequently, copulation take place. Often great swarms of winged ones appear in spring in an infested building and first call attention to the presence of the species.

Some of the eggs develop into the castes known as soldiers and workers. Here again there is a striking difference from the ants and other social Hymenoptera: the soldiers and workers are of both the male and female sex; but the reproductive organs are not usually developed. The workers and soldiers are entirely wingless throughout life, and generally blind. Nevertheless, they have a strong negative

reaction to light and rarely show themselves outside of the nest, the soil, or the wood in which they are working. If they must cross an exposed place, a covered runway of soil and body secretions is built. The workers build nests, supply food, care for the eggs, feed the young and the queens and kings, and perform all other duties for the colony. The mouth parts are of the chewing type; the mandibles of the soldier caste enormously enlarged, and borne on very large heads.

The food of termites is primarily wood, and often dead, hard wood, in which there is apparently little except cellulose, a material not usually digested by the larger animals. The digestive tracts are packed with protozoa, and it is believed that the termites live on the products of the digestion by the protozoa, and not on the cellulose directly. Termites are great pests of all kinds of products of wooden origin (see p. 30 and Figs. 15 and 16). They also attack living plants.

Termites are really a tropical group. In Africa and other tropical lands they build enormous nests, a dozen feet tall, containing incalculable numbers of workers. The queens of tropical species may reach a length of 4 or more inches, and they are said to produce eggs at the rate of 60 or more a minute.

Colonial insects, living in great nests or colonies, like ants, and with several castes. Abdomen wide where it joins the thorax, and with a pair of cerci at the end. Mouth parts chewing. Metamorphosis simple. Only the kings and queens normally reproduce; they are four-winged, often dark-colored. The wings are equal in size, long, narrow, with membrane somewhat thickened and the veins indistinct; laid flat over their backs when not in flight, and usually broken off after the pairing flight, along a joint of weakness near the base. The workers, soldiers and other castes do not regularly reproduce. They are wingless, usually pale-colored and soft-bodied.

ORDER CORRODENTIA (PSOCOPTERA, COPEOGNATHA)

Book Lice, Dust Lice, Bark Lice, Deathwatches

Often as one opens an unused book or disturbs some old papers, a very small yellow insect runs across the page. If one examines such an animated speck under a

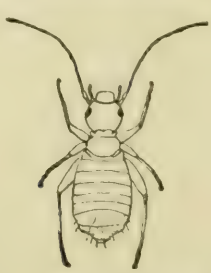

Fig. 106.—A book louse, greatly enlarged. (*From Comstock's "Introduction to Entomology," Comstock Publishing Co.*)

Fig. 107.—A winged bark louse, thirteen times natural size. (*From Kellogg's "American Insects."*)

lens, one finds a wingless, soft-bodied insect with well-developed head, chewing mouth parts, small compound eyes, antennæ nearly as long as the body, and six large legs

(Fig. 106). Relatives of this book louse live on the bark of trees and some of them have four membranous wings (rarely covered with scales like moths). They look like aphids but have the veins of the wing peculiarly kinked as shown in figure 107. At rest the wings are held rooflike over the back. A structural peculiarity of this order is the "pick" or rod attached to each maxilla and working in and out of the softer part of the maxilla like "a piston sliding to and fro in its cylinder."[1]

The known importance of this order is not very great. Those that live indoors may occasionally become pests by feeding on paper, starch, grain, and other substances in damp places, and one species has been accused of spreading plant diseases.

Minute insects; wingless or with four membranous wings with few veins; the first pair larger and at rest held rooflike over the abdomen. Mouth parts chewing, with a curious rod in the maxilla. Prothorax small, tarsi two- or three-segmented and cerci wanting. The metamorphosis is very simple.

ORDER MALLOPHAGA

Chewing Lice or Bird Lice[2]

There are two groups of lice that make their homes continuously on the bodies of warm-blooded animals. These two orders (Mallophaga and Anoplura) agree in never showing any trace of wings; in being flattened, oval, tough-skinned, external parasites; in gluing their eggs to the hairs or the feathers of the host; and in spending all their lives generation after generation on the same host animal. The members of the other order, the Anoplura, suck blood; but the Mallophaga have chewing mouth parts and subsist on bits of hair or feathers, skin scales or the dried blood from scabs. Another noteworthy difference is that, whereas the Anoplura are confined to the mammals or hair-bearing animals, the Mallophaga occur on both birds and mammals. By far the greatest number, however, are found on birds, nearly every kind of wild or domesticated bird being attacked by one or more kinds of chewing lice. As a general rule, one species of louse will seldom live on more than one species of bird; but the chicken has more than 40 species. Cattle, horses, sheep, dogs, and cats, also are attacked, but none of the chewing lice live on hogs or man. The species that live on birds normally run very rapidly when they are exposed. But the ones that live on mammals, have the tarsus highly modified into a clamp for clinging to the hairs, and move about but awkwardly. The nature of this clamp is explained in the discussion of the Anoplura, which have a similar structure (see Fig. 47, *E*). The metamorphosis is a very simple one; almost the only change from hatching to maturity being an increase in size, in thickness of the body wall, and in darkness of coloring.

[1] Maxwell Lefroy, *Manual of Entomology*, Longmans, Green & Co., 1923.

[2] These lice have often been called *biting lice* in an attempt to distinguish them from the Anoplura. This seems absurd, for if the victims of the attacks were asked which kind of lice "bite" they would undoubtedly say the Anoplura, which insert sharp stylets into the skin to suck the blood; and not these forms, which at most only nibble at the skin.

The chewing lice are small, wingless, flattened insects (see Figs. 545 and 546), *mostly* $\frac{1}{5}$ *to* $\frac{1}{25}$ *inch long, with large, broad heads, rounded in front, and bearing short antennæ often hidden in grooves of the head. The eyes are degenerate. The legs are not very large, tarsi one- or two-segmented, with one or two claws. The prothorax is distinct, and the body often covered with hairs. Mostly parasitic on the bodies of birds, but some species on mammals. Mouth parts chewing; not bloodsuckers; the labial palps, sometimes all four palps, wanting. No cerci. Metamorphosis gradual or wanting.*

Important species of Mallophaga are chicken lice and other lice of poultry (see p. 817), the little red louse or chewing cattle louse (see p.784), the chewing horse louse (p. 773) and the red-headed sheep louse (p. 807).

ORDER THYSANOPTERA

The Thrips (Fig. 108)

The thrips are minute, agile bugs, rarely as long as $\frac{1}{8}$ inch. They live in flowers or on other parts of plants, feeding on the sap. Many species are serious pests of fruits, vegetables, flowers, and field crops.

With the order Thysanoptera we take up the first insects with other than the chewing type of mouth parts. The mouth parts of thrips (see Fig. 69) are unique, in some respects being intermediate between the chewing and the piercing-sucking types. They have two pairs of palps, like the former, but the mandibles and maxillæ are suggestive of the form in the Hemiptera and Homoptera. The head bears well-developed compound eyes and ocelli, and well-developed but not extremely long antennæ. The head capsule tapers downward in the shape of a cone to a small mouth opening at its lowermost part (Fig. 108, *7*). Around this opening are the two maxillary and the smaller two labial palps. The labium is not elongated into a beak, but fused into the head cone. In and out of this funnel-like opening three slender jabbers or stylets operate by end thrusts to lacerate the epidermis of the plant. The sap which exudes is then sucked up through the mouth of the cone. The three stylets consist of the left mandible (the right being degenerated) and the two maxillæ.

Two other structural peculiarities of thrips, the wings and the tarsi, need explanation. In some species one of the sexes and in other species both sexes, are wingless. Many of the species have four wings which are extremely narrow and almost without veins. The wing membrane would scarcely be sufficient to sustain the insects in flight. The wing, however, is fringed with close-set long hairs to furnish resistance to the air in flight, somewhat like the long feathers on the wing of a bird. This gave the order the name Thysanoptera, which means *bristle wings*. The other peculiarity is in the foot. The tarsus has one or two segments but no claws. It ends in a hooflike or cuplike depression surrounding a small bladder that can be protruded or withdrawn by the insect. This charac-

teristic gave the insects the name Physopoda (*bladder-footed*), which is sometimes used instead of Thysanoptera.

Thrips are very active insects, at least when disturbed. They spring or fly readily, they turn up their tails at one, as if to sting, and, according to one writer, they spend most of their time combing the hairs of the body. The eyes are small.

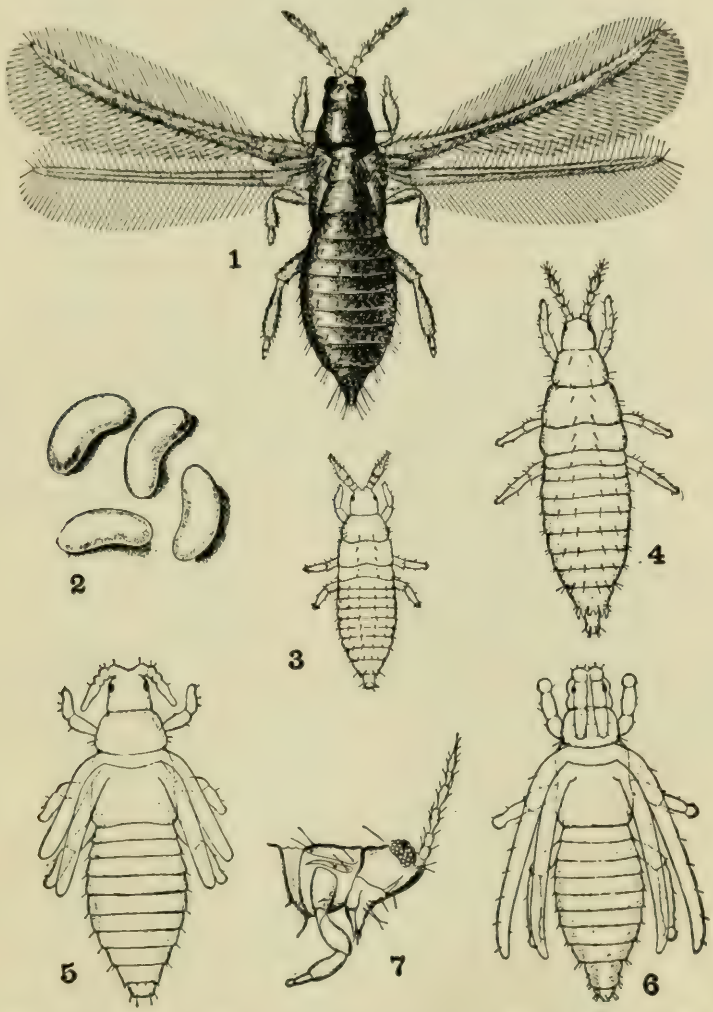

FIG. 108.—The pear thrips (*Tæniothrips inconsequens* Uzel.) 1, adult; 2, eggs; 3, first instar nymph; 4, second instar nymph; 5, third instar nymph; 6, last instar nymph; 7, head of adult from the side. All greatly enlarged. (*Reduced from Moulton, U. S. D. A. Dept. Bull.* 173.)

The eggs are laid on the tissues of plants, or, in some species, inserted into slits made by a sharp ovipositor. Parthenogenesis is common. There are four or more nymphal instars. The last two do not feed and may be quite inactive—a foreshadowing of the complete metamorphosis of the higher orders. There are a number of destructive species, such as the onion thrips (p. 493), camphor thrips, greenhouse thrips (p. 710), pear thrips, and oat thrips.

Small to minute, mostly phytophagous, slender-bodied insects, wingless or with two pairs of very slender, nearly veinless, wings fringed with long hairs

and laid longitudinally over the back when not in use. Mouth parts rasping, asymmetrical, with two pairs of palps but only one mandible. The tarsus terminates in a protrusible bladder. Cerci wanting. Metamorphosis gradual, but the larger nymphal stages quiescent.

ORDER HOMOPTERA (HEMIPTERA OR RHYNCHOTA, IN PART)

THE CICADAS, APHIDS, SCALE INSECTS, LEAFHOPPERS, TREEHOPPERS, AND OTHERS

For many years authors included the above kinds, together with the leaf bugs, stink bugs, bedbugs, squash bugs, water bugs, and their

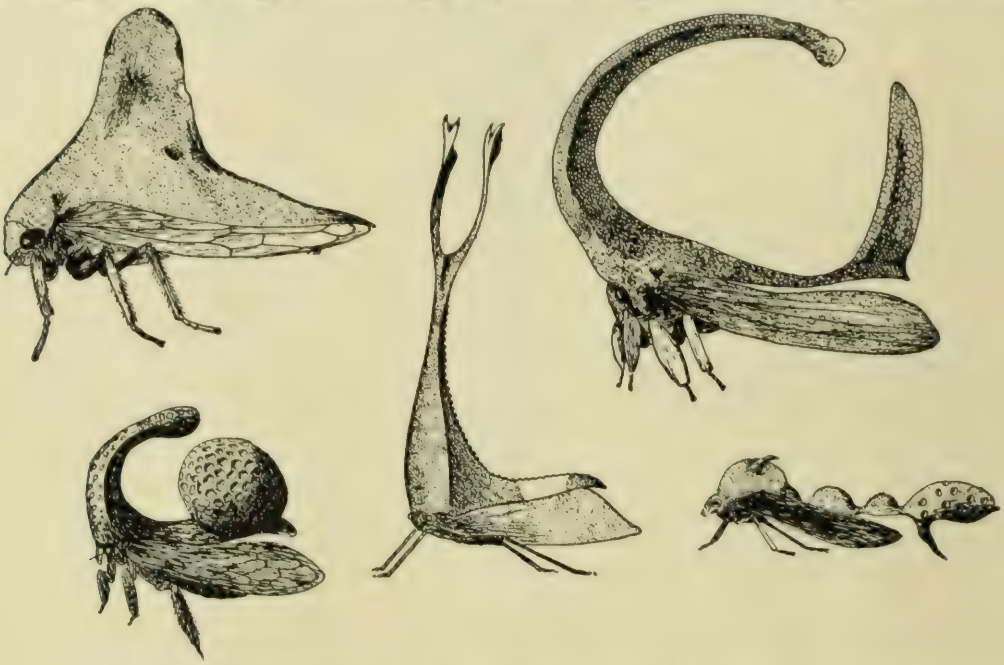

FIG. 109.—A group of treehoppers or membracids showing the remarkable development of the pronotum. (*From Funkhouser, Cornell Agr. Exp. Sta.*)

relatives, all in the order Hemiptera. They have important points in common. *They have a gradual metamorphosis. The mouth parts of all of them are of the piercing-sucking type, without palps. There are four wings*

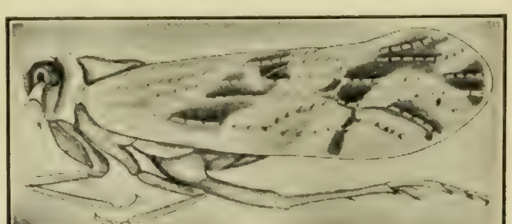

FIG. 110.—A fulgorid, *Stobaera tricarinata* Say. (*From Z. P. Metcalf, Jour. Elisha Mitchell Sci. Society, Vol.* XXXVIII.)

or none. The antennæ are of few segments. Compound eyes and ocelli are usually present and cerci wanting.

They have such important differences, however, that most recent authors separate the above groups into two orders, Homoptera and

Hemiptera. Except for the cicadas, the Homoptera are mostly small, inconspicuous insects. Some, however, are brilliantly colored and many are of grotesque shapes. Many of them are wingless, at least in the female sex or under certain conditions. *When wings are present they*

FIG. 111.—Masses of spittle made by the grass-feeding spittle bug, as a protection for the nymphs which live within it. About three times natural size. (*From Osborn, Me. Agr. Exp. Sta. Bull.* 254.)

are four in number, of a nearly uniform, membranous, or sometimes somewhat leathery texture; the front pair is longer, the hind pair wider; they usually stand sloping roof-shaped over the abdomen when at rest; and they do not overlap much at the tip. Male scale insects are an exception, having only one pair of wings (Fig. 350) and a complete metamorphosis.

Some are very degenerate in form; the female scale insects having neither body regions, eyes, wings, nor legs (Fig 63, *Fe*).

FIG. 112.—Adult spittle bug, parent of the nymphs which make the masses of spittle. (*From Garman, Conn. Agr. Exp. Sta. Bull.* 230.)

The labium or beak of the Homoptera attaches to the head near its hinder part, often seeming to arise from between the front legs, which touch the head; sometimes the labium is very short, apparently wanting. The food is exclusively the sap of plants. There are many extremely destructive species, some carrying diseases from plant to plant. The following are among the more destructive species of this order: the San José, scurfy, and oyster-shell scales (see pp. 539, 544), the terrapin scale (p. 603), greenhouse scale insects (p. 700), apple aphids (p. 545), corn root aphid (p. 314), aphids of many vegetable crops (pp. 442, 503), greenhouse aphids (p. 707), greenhouse and citrus whiteflies (pp. 709, 657), apple and beet leafhoppers (pp. 475, 512), the buffalo treehopper (p. 537) and the periodical cicada (p. 533). The student should study the figures and descriptions of these typical species of Homoptera.

The important families are listed in the following:

SYNOPSIS OF THE ORDER HOMOPTERA

A. Suborder *Auchenorhynchi*. The Free Beaks. Labium plainly attaches to head. Tarsi three-segmented. Active, free-moving insects. Antennæ very small, ending in a bristle. Medium-sized to very large insects.

Family 1. The cicadas ("locusts"), Family Cicadidæ
Family 2. The spittle bugs or froghoppers, Family Cercopidæ (Figs. 111, 112)
Family 3. The treehoppers, Family Membracidæ (Fig. 109)
Family 4. The leafhoppers, Family Cicadellidæ (Jassidæ)
Family 5. The planthoppers, Family Fulgoridæ (Fig. 110)

B. Suborder *Sternorhynchi*. The Fused Beaks. Labium appears to attach to the thorax between the front legs. Tarsi one- or two-segmented. Females sluggish or sedentary. Antennæ larger, not ending in a bristle. Nearly all very small insects.

Family 6. The jumping plant lice, Family Chermidæ (Psyllidæ)
Family 7. The plant lice or aphids, Family Aphididæ
Family 8. The whiteflies, Family Aleyrodidæ
Family 9. The scale insects, Family Coccidæ

ORDER HEMIPTERA (HETEROPTERA, OR RHYNCHOTA, IN PART)

THE TRUE BUGS

These bugs (Fig. 113) *are like the Homoptera in having a gradual metamorphosis, two pairs of wings, antennæ of five or fewer segments, piercing-sucking mouth parts and the hind wings usually shorter and wider than the front pair. They are distinguished from the Homoptera by*

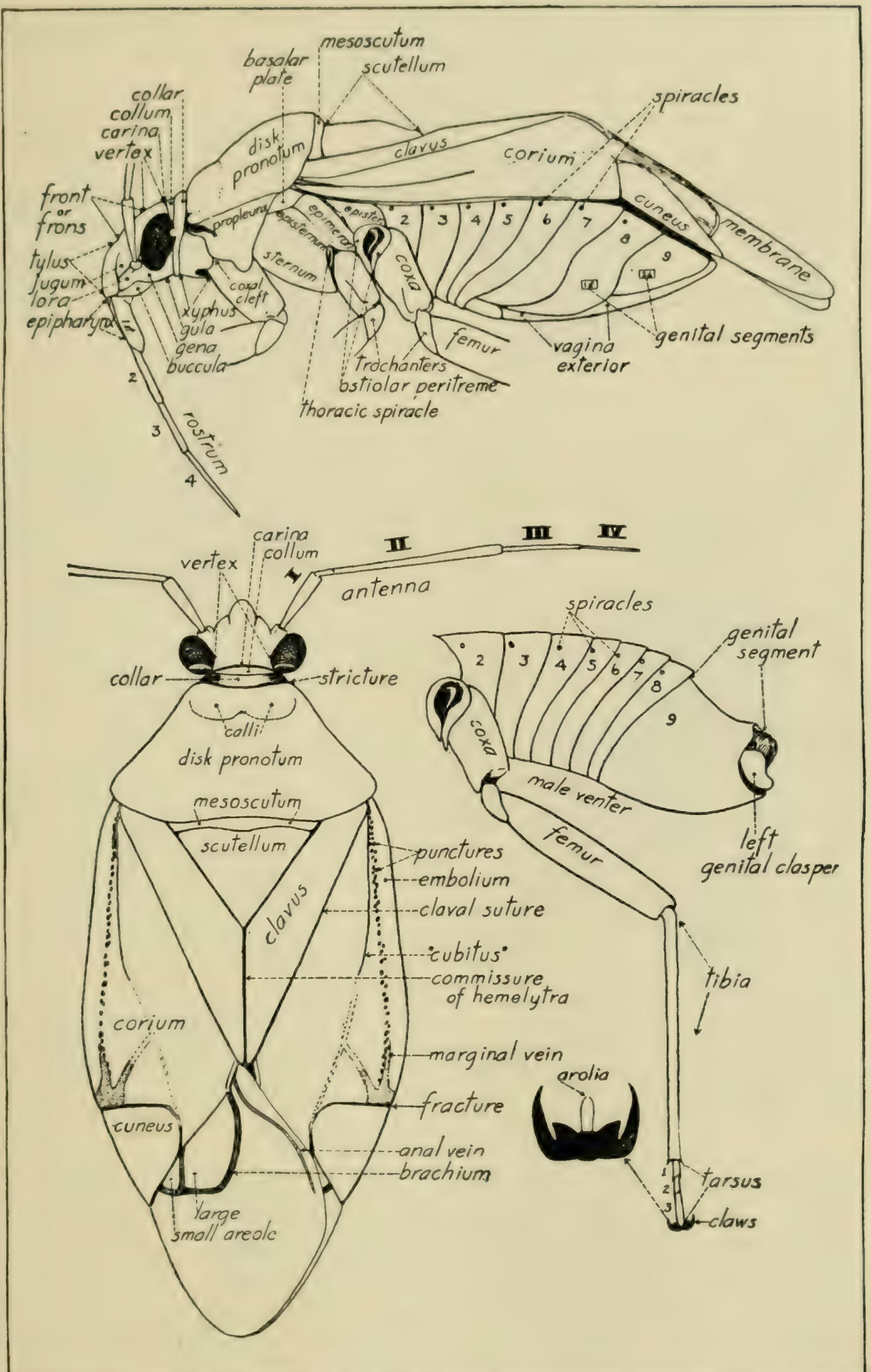

FIG. 113.—A bug of the order Hemiptera (*Deraeocoris fasciolus* Knight), with the principal parts of the body named. The part labeled epipharynx is called the *labrum*, and the rostrum, the *beak*, by some authorities. The parts of the wing labeled *clavus*, *corium* and *cuneus* are thick and horny; the part labeled *membrane* is thin and transparent. (*From Knight, Minn. Agr. Exp. Sta. Tech. Bull.* 1.)

having the front pair of wings thickened and quite stiff over about the basal half, the distal half abruptly thinner, usually membranous. When folded back they lie horizontally, or flat, over the back, and the membranous tips of the front pair overlap. There are many wingless forms and some adults with short wings often in the same species with long-winged ones.

The labium or beak of the Hemiptera attaches well forward near the front end of the head, and the head is free from the coxæ and longer than it

FIG. 114.—A giant water bug or electric-light bug, *Lethocerus americanus* (Leidy). Natural size. (*From Kellogg's "American Insects."*)

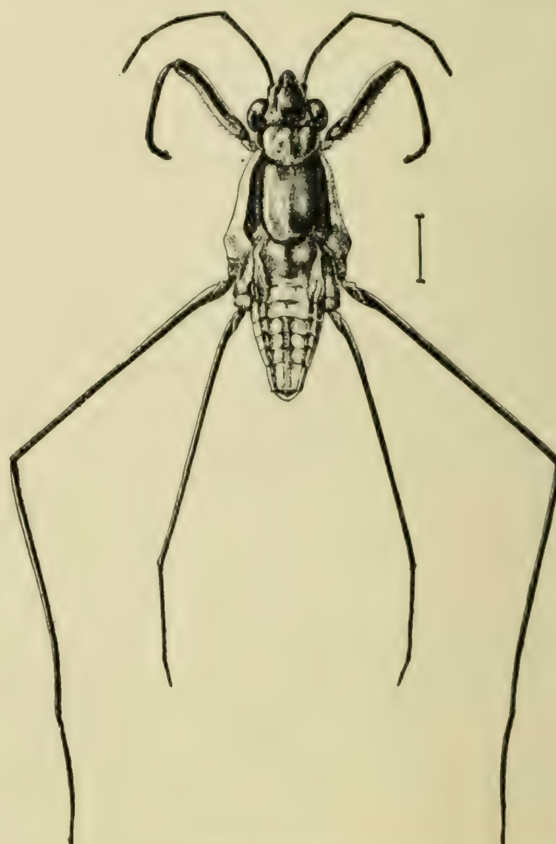

FIG. 115.—A water strider. The line shows actual length of body. (*From Osborn, "Agricultural Entomology."*)

is in the Homoptera. All of this order are insect-like in form, there being no extremely degenerate species. *They commonly possess scent glands that give them a distinct odor,* usually offensive to man and probably defensive against their natural enemies. The various species attack a wide variety of both plants and animals, always feeding on liquid parts only. Those that attack plants generally have the labium long and straight; those that prey on other insects or on larger animals, have a short, curved labium.

A few of the most important species of Hemiptera are: the chinch bug (p. 344), squash bug (p. 462), harlequin cabbage bug (p. 501), tarnished plant bug (p. 445), apple red bug (p. 582), bedbug (p. 836) and

assassin bugs (p. 837). The figures of these typical Hemiptera should be examined to illustrate the above characteristics.

Fig. 116.

Fig. 117.

Fig. 118.

Fig. 116.—An ambush bug, *Phymata erosa* (Linné). *a*, adult from above; about twice natural size; *b*, the same from the side, more enlarged; note the enormous femur of the grasping front leg. (*From Fernald's "Applied Entomology," after Riley.*)

Fig. 117.—A lace bug (*Corythuca arcuata* Say). The line shows actual length. (*From Comstock's "Introduction to Entomology," Comstock Publishing Co.*)

Fig. 118.—The box-elder bug, *Leptocoris trivittatus* (Say). Twice natural size. (*From Kellogg's "American Insects."*)

The important families are listed in the following:

SYNOPSIS OF THE ORDER HEMIPTERA

A. Suborder *Cryptocerata.*—The Short-horned Bugs. Antennæ shorter than the head, nearly concealed on the under side of the head. Stink glands wanting.

1. *Aquatic Predaceous Bugs.*
    - Family 1. Water boatmen, Family Corixidæ
    - Family 2. Back swimmers, Family Notonectidæ
    - Family 3. Water scorpions, Family Nepidæ
    - Family 4. Giant water bugs, Family Belostomidæ (Fig. 114)

B. Suborder *Gymnocerata.*—The Long-horned Bugs. Antennæ at least as long as head and plainly visible at its sides.

2. *Semiaquatic Predaceous Bugs.*
    - Family 5. Water-striders, Family Gerridæ (Fig. 115)
3. *Terrestrial Predaceous Bugs.*
    - Family 6. Assassin bugs, Family Reduviidæ
    - Family 7. Bedbugs, Family Cimicidæ
    - Family 8. Thread-legged bugs, Family Emesidæ
    - Family 9. Damsel bugs, Family Nabidæ
    - Family 10. Ambush bugs, Family Phymatidæ (Fig. 116)
    - Family 11*a*. Stink bugs, Family Pentatomidæ (in part)
    - Family 12*a*. Leaf bugs, Family Miridae (Capsidæ) (in part)
4. *Terrestrial Plant-eating Bugs.*
    - Family 11*b*. Stink bugs, Family Pentatomidæ (in part)
    - Family 12*b*. Leaf bugs, Family Miridæ (Capsidæ) (in part)
    - Family 13. Lace bugs, Family Tingidæ (Fig. 117)
    - Family 14. Chinch bugs and others, Family Lygæidæ
    - Family 15. Squash bug, Leaf-footed Bugs, and others, Family Coreidæ (Fig. 118)

ORDER ANOPLURA (SIPHUNCULATA OR PARASITA)

The Blood-sucking Lice

These lice should be distinguished from the chewing lice. These are much the more serious kind. They live exclusively by sucking the blood of the host, and in so doing are very likely to be carriers of diseases. The members of this order are small, wingless, tough-skinned, flattened, usually dark-colored, external parasites. They attack all kind of wild and domesticated mammals, but none are known to live on any other class of host. Two species attack man—the cootie, body louse or head louse (p. 849), and the crab louse (p. 853). The first of these is the carrier of typhus fever and trench fever. The largest species are about ¼ inch long. They can be distinguished from Mallophaga by the difference in mouth parts, and by the relatively narrower, more pointed head. The antennæ are short, but usually conspicuous. The thorax is not marked off from the abdomen, and the three segments are fused together. The legs are relatively very heavy and are highly specialized to enable the insects to hold on with a deathlike grip to the hairs. The tarsus is a single segment with one enormous claw (Fig. 47, *E*). This is drawn around by muscles to clamp against a thumblike projection from the end of the tibia, gripping the hair between the claw, the tarsal segment, the end of the tibia, and its thumb. In some species a spiny pad is forced out from the end of the tibia, further to strengthen the grip.

The mouth parts (Fig. 68) are unique. They are of the piercing type, but when not in use are completely withdrawn into the head of the louse. All one can usually see externally is a fringe of minute teeth at the foremost part of the head. At a short distance inside this fringe the mouth cavity divides into two tubes. The upper tube is the pharynx, which leads on to the stomach; the lower tube is only about as long as the head and ends blindly like an introverted glove finger. In this blind tube is a complicated set of stylets, in their simplest form described as a dorsal and a ventral stabber, attached near the blind, posterior end of the tube, free at their front ends. Muscles are so arranged as to drive these stylets into the flesh. Saliva is carried down into the wound through the stylets, but apparently they do not form a food channel, the blood flowing out to the surface and being sucked up directly into the pharynx, through the closely appressed mouth opening.

The eggs of Anoplura, often called "nits," are glued fast to the hairs, or in one species, laid in seams of clothing while it is being worn. The metamorphosis is very simple. The entire life is spent on the body of the host. For the most part, each species attacks one species of host and can live on no other. The eyes are very degenerate or wanting; ocelli absent.

Small, wingless, flattened, external parasites of mammals. Mouth parts retractile, piercing-sucking. Head narrow, pointed in front; eyes wanting or degenerate. Thoracic segments fused; tarsi of one segment with a single, grasping claw. Metamorphosis simple.

Less than 150 species are known, but their habits give to this order an importance out of all proportion to its size. The species attacking man belong in the family Pediculidæ (see p. 849). The family Hæmatopinidæ includes the species attacking domestic animals. Important species are the hog louse (p. 798), the blood-sucking horse louse (p. 774), the short-nosed and long-nosed ox lice (p. 786), and the blood-sucking sheep lice (p. 807).

INSECTS WITH A COMPLETE METAMORPHOSIS

With the Anoplura we completed our discussion of the orders that have a gradual or simple metamorphosis. All of the orders that follow have a complete or complex metamorphosis. A glance at Table VI, on p. 171 will show that the four largest orders are in this group, and a little checking of the species of economic importance, discussed in the following chapters, will show that most of our destructive insects are representatives of one of the following orders. Apparently the complete metamorphosis is a very successful thing, in spite of the fact that insects undergoing such transformations must usually become adapted to three distinctly different environments during the course of the life cycle. In the case of gradual metamorphosis, the same environment usually serves for both nymphs and adults; but in complete metamorphosis the larva must find suitable food, the pupa must be protected from enemies and adverse physical conditions, and the adult must again find food (generally different from that of the larva) or, if it does not feed, at least a suitable place to deposit eggs.[1]

ORDER COLEOPTERA

The Beetles and Weevils

This is the largest of all orders of insects. Two out of every five kinds of insects that have been discovered and named are beetles. This may be due in part to the fact that most of the orders have not been studied as extensively as the beetles have. Nevertheless ordinary observation will show that these insects are so numerous and ubiquitous, and of such diverse form, habit, and appearance, that not to know something about the beetles is to remain in ignorance of a large and very interesting part of our environment. It is well to study beetles also in self-defense, for they attack us at every point, feeding on growing

[1] See "The Life Cycle in Insects," In *Annals Entomol. Soc. Am.*, Vol. 13, pp. 133–201, June, 1920.

crops of all kinds, from forest trees to greenhouse plants, as well as on stored foods and other possessions. It is noteworthy that there are practically no beetles that attack the larger animals, and very few *parasites* on any group, although many of them are predaceous on insects and other small animals.

The most characteristic thing about beetles is their wings (Fig. 119). The mature insects have the front wings specialized into what are called *elytra* (pronounced ell'-it-ra). These are greatly thickened by chitin so that they usually show no veins, and they are not flapped in flight, but serve as a pair of convex shields to cover the hind wings and the rather delicate-walled abdomen from above. When the insect is not flying they lie close over the abdomen, the inner edges of the two coming together to form a straight line from the prothorax back to the tip of the wings, neatly covering the mesothorax, the metathorax, and at least part of the abdomen (note Figs. 123 and 125). A small part

Fig. 119.—A beetle, *Ligyrodes relictus* (Say), with wings spread; the left one showing how the large hind wings fold beneath the elytra or front wings as they are laid back over the abdomen. (*Original.*)

of the mesothorax, known as the *scutellum*, remains exposed as a little triangle between the bases of the elytra. On account of the nature of the front wings, the prothorax is unusually distinct from the rest of the thorax, and is often wrongly called "the thorax."

The hind wings, or second pair, are the real organs of flight. When a beetle flies, the front wings are held stiffly out at the sides of the body, while the hind wings, only, beat so rapidly that one can scarcely see them. These wings are about as wide as the elytra but commonly one-fourth or one-third longer. They do not project beyond the elytra when the insect comes to rest, but by a remarkable automatic "joint" the distal third or fourth is folded under as the wings are laid back to the resting position (Fig. 119). The second pair of wings are thin and membranous, with a few veins. Sometimes these hind wings, and rarely both pairs, are wanting, or the wings may be grown together so they cannot be moved.

The mouth parts of beetles are of the chewing type in both larvæ and adults, the same parts being recognizable as in grasshoppers or crickets (see p.112). One can usually tell something of the habits of a beetle by

examining its teeth. If the mandibles are short, chunky, and with a small number of blunt denticles on the mesal face, it indicates a species that takes plant food. If the mandibles are elongate, come out to one or two sharp points toward the end, or have the inner edges sharp for cutting, the insect is carnivorous and probably beneficial to us by eating other insects.

In one group of this order (the snout beetles) the head is prolonged forward and downward into a cylindrical snout (Fig. 120) that varies

FIG. 120.—A snout beetle, *Sphenophorus æqualis* Gyll., to show prolongation of the head into a snout; above in side view, below, dorsal view. (*From Illinois State Nat. Hist. Sur.*)

FIG. 121.—A tiger beetle and, in the tunnel, a larva of the same. About natural size. (*From Sanderson and Jackson after Linville and Kelly.*)

in length from shorter than the rest of the head to several times the length of the whole body. The student must be careful not to confuse such a snout with the beak of the Homoptera or Hemiptera. This snout is not the mouth parts, but a part of the epicranium, as indicated by the attachment of the antennæ to it. It is not jointed, it is not furrowed down the front, and it of course contains no stylets. The mandibles, maxillæ, etc., are found on the end of the snout, being very small but functioning as chewing mouth parts. This long snout is used for making a hole deep into the tissues of plants, in which the eggs are laid. It also enables its possessor to eat the tissues beneath the surface.

Beetles generally have no ocelli in the adult stage, though the compound eyes are well developed. The reverse is true of the larvæ, which have a small group of ocelli at each side of the head but never compound eyes. The coxæ of the hind legs (Fig. 47, *F*) are flattened out like a part of the body wall, instead of articulating into a socket of the latter, so that these legs at first sight appear to lack the coxæ. There are no cerci. The Coleoptera embrace many very small insects and from these upward in size to some tropical kinds that are several inches in length. There are very few insects likely to be confused with the Coleoptera. A few kinds of Hemiptera have a superficial resemblance to beetles, but the shield over the back is not formed of two wings but is a single piece, an over-


Fig. 122.


Fig. 123.


Fig. 124.


Fig. 125.

Fig. 122.—A rove-beetle, *Creophilus maxillosus* (Linné). Enlarged one-half. (*From Kellogg's "American Insects."*)

Fig. 123.—A burying beetle, *Necrophorus marginatus* (Fabricius). Enlarged one-half. (*From Kellogg's "American Insects."*)

Fig. 124.—The giant water scavenger beetle, *Hydrous triangularis* (Say). Natural size. (*From Kellogg's "American Insects."*)

Fig. 125.—A firefly or lightning beetle (*Photinus scintillans* Say). Three times natural size. The insect gives off flashes of light, while flying at night, from the end of the abdomen on the under side. (*From Kellogg's "American Insects."*)

grown thorax (see Fig. 331). The earwigs look much like the rove beetles (*cf.* Figs. 101 and 122), but always show at the tip of the abdomen a pair of heavy forceps or pinchers.

Beetles all have a complete, sometimes a very complex, metamorphosis. The larvæ of beetles (Figs. 195, 197, 307, *b* and 517) are generally called grubs, sometimes borers. They can be recognized by the following characters: They commonly have six thoracic legs each ending in one or two claws, but some are entirely legless. There are never a series of prolegs; at most one pair at the tip of the body, and these having no crochets on the end of them. The head never has the *adfrontal area* that characterizes Lepidopterous caterpillars. The spinneret at the middle of the labium also is wanting. The head is always distinct, usually dark-colored, bearing definite though often minute antennæ. There are always

a number of pairs of spiracles on the abdominal segments. The larvæ are very diverse in shape.

The pupæ of the beetles (Fig. 195 and 270, *h*) can be distinguished from other pupæ by noting that all the mouth parts are of the chewing type and that the antennæ have fewer than 12 segments. The membranous sacs that enclose the antennæ, legs, and wings are not grown fast ("cemented down") to the sides of the body, but are free and can be moved about. Beetle pupæ are not protected by the dense silken cocoons characteristic of moth pupæ. They may have thin cocoons, but are often openly exposed on leaves; at other times hidden in the soil, in burrows in wood, or covered over with foreign material accessible to the larva as it prepares for pupation.

FIG. 126.—A stag beetle, *Lucanus elaphus* Fabricius, male, natural size. (*From Kellogg's "American Insects."*)

In this order, both larvæ and adults are commonly injurious and in the same manner. Sometimes, however, the habits of larvæ and adults are different, so that they may be injurious in two totally different ways; or one or the other only may be destructive. In a few cases one life stage is harmful to us and the other beneficial; thus the blister beetles (see p. 474) as adults feed on the foliage of potatoes, chard, asters, and other plants, while their larvæ are helpful to man by eating the eggs of grasshoppers in the soil. The lady beetles, except for a few species, and many species of ground beetles are highly beneficial, both as larvæ and adults, by devouring injurious insects (see p. 56).

The Coleoptera are minute to very large, usually heavily-chitinized, robust insects. The front wings are much thickened, veinless, and meeting in a middorsal straight line; the hind wings membranous, with few veins, and the apex folded under transversely when at rest. Mouth parts of typical chewing type, although in the snout beetles they are reduced and placed at the end of a slender trunklike snout easily mistaken by the tyro for piercing mouth parts. Ocelli generally wanting, antennæ mostly of 11 *segments. Prothorax very distinct from meso- and meta-thorax, which are united with the abdomen. Metamorphosis complete. Larvæ wormlike or shaped like Thysanura, usually with six thoracic legs and not more than one pair of prolegs, rarely apodous. Spiracles on principal segments. No adfrontal area. Pupæ with appendages free; rarely in cocoons.*

Among the many, very destructive species are the following, to which the student should refer for figures and descriptions of typical species:

White grubs (p. 306), wireworms (p. 303), billbugs (p. 342), corn rootworms (p. 310), clover bud weevil (p. 390), alfalfa weevil (p. 387), cucumber beetles (p. 459), Colorado potato beetle (p. 472), flea beetles (p. 437), Mexican bean beetle (p. 451), bean and pea weevils (p. 763), sweet-potato beetles (p. 483), asparagus beetle (p. 516), bark beetles (p. 602), flat-headed and round-headed apple borers (p. 526), Japanese beetle (p. 605), strawberry weevil (p. 643), plum curculio (p. 577), tobacco beetle (p. 744), buffalo beetles or "moths" (p. 746), grain beetles (p. 755), granary and rice weevils (p. 753), meal worms (p. 756), and larder beetle (p. 750).

Only the most important families are listed in the following:

SYNOPSIS OF THE ORDER COLEOPTERA

A. **Suborder** *Adephaga*.—The Predaceous Beetles. Mostly feed on other insects. Largely beneficial to us. Tarsi of five segments. Antennæ generally filiform. Ventral part of first segment of abdomen divided into three areas by the hind coxæ—a very small median piece between the coxæ and two large side pieces. Larvæ with six segments in each leg and two claws at the end of the leg.

1. *Terrestrial Predaceous Beetles.*
    - Family 1. Tiger beetles, Family Cicindelidæ (Fig. 121)
    - Family 2. Ground beetles, Family Carabidæ
2. *Aquatic Predaceous Beetles.*
    - Family 3. Predaceous diving beetles, Family Dytiscidæ
    - Family 4. Whirligig beetles, Family Gyrinidæ

B. **Suborder** *Polyphaga*.—Beetles of a great variety of form, habit, and economic importance. All have the first ventral segment of the abdomen in a single piece, not divided by the hind coxæ. The legs of the larvæ end always in a single claw and have five segments or fewer.

3. *The Short-winged Beetles or Brachyelytra.*
    Elytra short, exposing much of the abdomen. Tarsi five-segmented.
    - Family 5. Rove beetles, Family Staphylinidæ (Fig. 122)
    - Family 6. Carrion or burying beetles, Family Silphidæ (Fig. 123)
4. *The Club-horned Beetles or Clavicornia.*
    Antennæ clavate. Tarsi five- or three-segmented.
    - Family 7. Water scavenger beetles, Family Hydrophilidæ (Fig. 124)
    - Family 8. Flat bark beetles, Family Cucujidæ
    - Family 9. Lady beetles, Family Coccinellidæ (Tarsi three-segmented)
    - Family 10. The skin beetles, Family Dermestidæ
5. *The Saw-horned Beetles or Serricornia.*
    Antennæ serrate. Tarsi five-segmented.
    - Family 11. Firefly or lightning beetles, Family Lampyridæ (Fig. 125)
    - Family 12. Soldier beetles, Family Cantharidæ
    - Family 13. Metallic wood borers, Family Buprestidæ
    - Family 14. Click beetles, Family Elateridæ
6. *The Beetles with Different-jointed Tarsi or Heteromera.*
    Five segments in tarsi of front and middle legs; four segments in hind tarsi.
    - Family 15. Darkling beetles, Family Tenebrionidæ
    - Family 16. Blister beetles, Family Meloidæ

7. *The Leaf-horned Beetles or Lamellicornia.*
   Tarsi five-segmented throughout. Antennæ lamellate, a cylindrical basal part and a number of flattened leaflike segments at the tip.
   Family 17. The stag beetles, Family Lucanidæ (Fig. 126)
   Family 18. The lamellicorn beetles, Family Scarabæidæ
8. *The Plant-eating Beetles or Phytophaga.*
   Tarsi apparently four-segmented.
   Family 19. The long-horned beetles, Family Cerambycidæ
   Family 20. The leaf beetles, Family Chrysomelidæ
   Family 21. The pea and bean weevils, Family Mylabridæ (Bruchidæ)
9. *The Snout-beetles or Rhynchophora.*
   Head often produced into a long snout. Tarsi apparently four-segmented Antennæ clubbed and elbowed.
   Family 22. Typical weevils, Family Curculionidæ (Fig. 120)
   Family 23. Engraver or bark beetles, Family Scolytidæ

ORDER STREPSIPTERA

Stylops or Twisted-wing Parasites

This is a small order of minute, internal parasites of insects, of little or no importance to man because they destroy mostly wild bees, wasps, and a few leafhoppers.

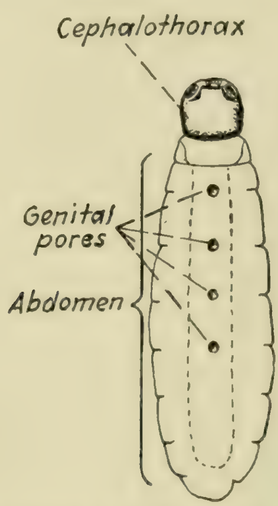

Fig. 127.—A full-grown or adult female strepsipteron (*Xenos vesparum*). (*Redrawn from Imms, "General Textbook of Entomology," after von Siebold.*)

They are so abnormal in structure as to constitute an order of very distinct characteristics.

Males (Fig. 128) *with stalked eyes, flabellate antennæ, and degenerate chewing mouth parts. Wings four, but the first pair reduced to mere short clubs, the hind pair large, triangular, folding fanlike and without cross-veins. Female* (Fig. 127) *without legs, wings, eyes or antennæ, and the mouth parts mere vestiges; wormlike and living in the interior of insects throughout life except for the fused head and cephalothorax, which project like a lump, or tumor, between two segments of the host. Her body is enclosed in the last larval skin, which is open just behind the head into the brood chamber. This communicates with the unpaired genital pores on several abdominal segments, and serves for fertilization and also for the escape of the larvæ. Metamorphosis is complete, with a hypermetamorphosis.*

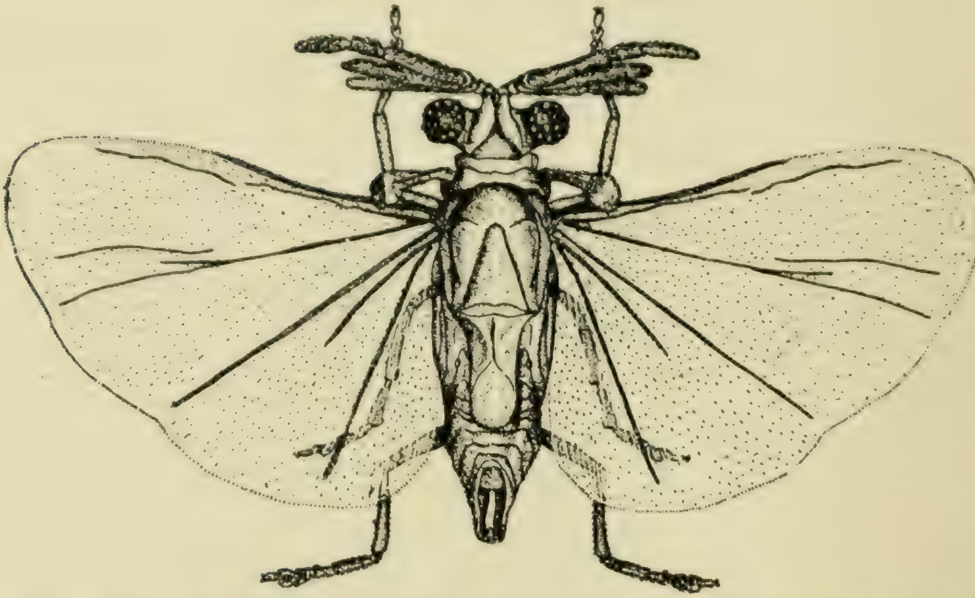

FIG. 128.—An adult male strepsipteron (*Muirixenos dicranotropidis*). Note the flabellate antennæ, the club-like front wings and the veinless hind wings. (*From Pierce, Proc. U. S. Nat. Mus. Vol.* 54.)

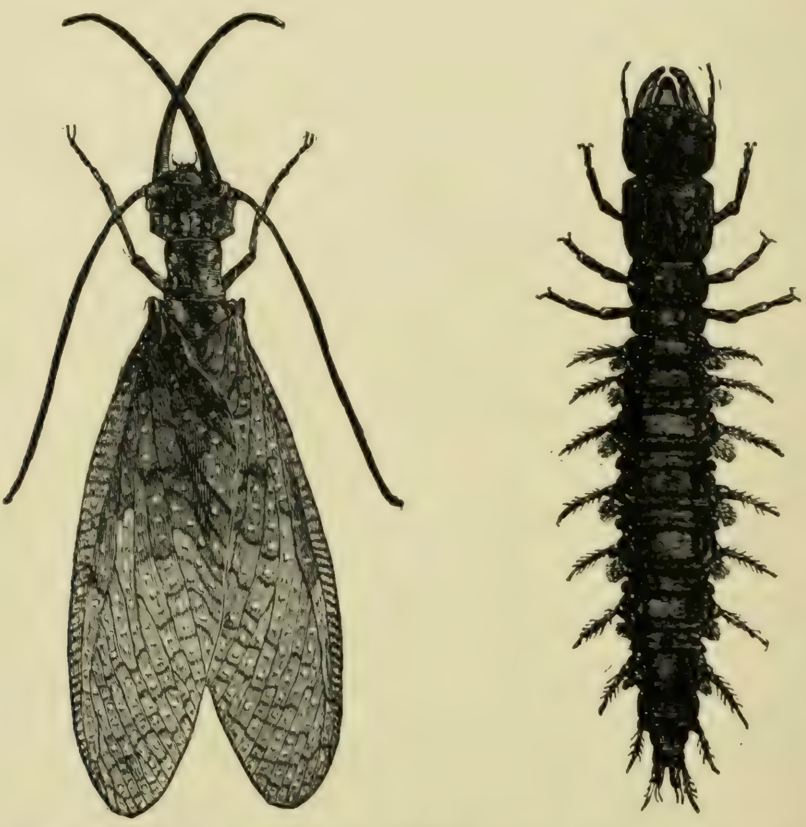

FIG. 129.—The Dobson-fly, *Corydalis cornuta* Linné; adult male on the left and its larva, the hellgramite, on the right. Natural size. Note enormous mandibles of the male and the short hair-like tufts of tracheal gills on the abdomen of the larva. (*From Sanderson and Jackson, "Elementary Entomology," after Comstock.*)

ORDER NEUROPTERA

APHID-LIONS, DOBSON-FLIES (FIG. 129), ANT-LIONS (FIG. 130) AND OTHERS

This order includes species which are mostly predaceous and beneficial to man. The aquatic forms serve as food for fish, and the terrestrial ones are very beneficial in their larval stages by preying upon aphids, ants, and other small insects (see also p. 55).

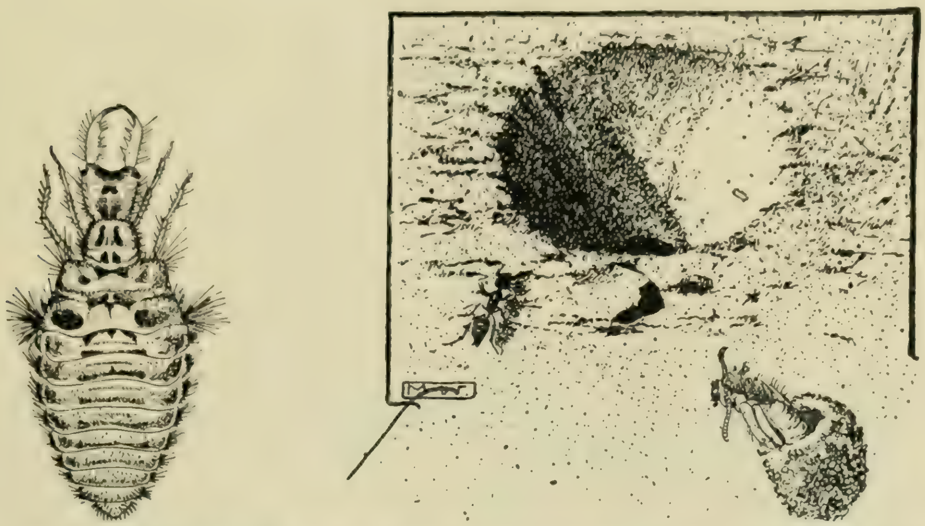

FIG. 130.—The ant-lion or "doodle bug;" *Myrmeleon* sp.; larva on the left, three times natural size. Note the elongate mandibles adapted for sucking. On the right is shown the sand pit or trap made by the ant-lion to catch ants, at the bottom of which the larva lives; about half natural size. Below is the empty pupal skin and the sand-covered cocoon from which the adult has escaped. (*From Kellogg's "American Insects."*)

Insects of variable size, large or small, with four large leaflike wings of nearly equal size: generally finely net-veined and held rooflike over the abdomen at rest. Mouth parts of the chewing type, though secondarily adapted in many of the larvæ (Fig. 32 *b*, *d*) *for sucking the blood of other small animals, each mandible having a ventral groove closed by the maxilla to form a sucking tube. Antennæ generally long, cerci wanting, tarsi of five segments. Larvæ spindle-shaped, carnivorous, many of them aquatic with tracheal gills on the abdominal segments* (Fig. 129).

ORDER MECOPTERA

THE SCORPION-FLIES

This order includes some seldom-noticed insects of little or no economic importance. The common name is given because the males of some of the species (*Panorpa*) have the tip of the abdomen swollen and carry it curved upward in a manner suggestive of the sting of a scorpion (Fig. 131).

FIG. 131.—A scorpion-fly, *Panorpa rufescens* Ramb., twice natural size. Note the "sting-like" or scorpion-like tail. (*From Kellogg's "American Insects."*)

The most distinctive characteristic is the prolongation of the head, maxillæ, and labium into a broad snout two of three times as long as the width across the eyes. At the end of this snout are the chewing mouth parts. The four, long, rather narrow wings have rather numerous cross veins. The larvæ are caterpillar-like, but

are distinguishable from Lepidoptera because some of them have eight pairs of prolegs without crochets, while others have no prolegs; and the pupæ have the wing cases and leg cases free from the sides of the body.

ORDER TRICHOPTERA

Caddice-flies (Fig. 133) and Caddice-worms (Fig. 132)

This order includes about 2,000 species of mothlike insects that are seldom seen except along streams or lakes, in the water of which the larvæ develop. The adults are commonly less than 1 inch in length, and have four brownish wings covered with hairs and held sloping rooflike at the sides of the body. The mouth parts are greatly reduced. There are no mandibles and probably most adults take no food.

The eggs (Fig. 73, *P*) are laid in ropes or masses of gelatin-like or cement-like substance in or near the water, often under stones in streams. The larvæ are the best known. They make cases that cover their bodies, except the head and legs (Fig. 85, *F*, *G*, *N*) and often drag these protective cases about with them on the bottom of ponds

Fig. 132.

Fig. 133.

Fig. 132.—Caddice-fly larvæ; above, larva in its case with head and legs projecting in normal position; below, larva removed from its case to expose the tracheal gills on the abdomen. (*From Fernald's "Applied Entomology," after Leuckhart.*)

Fig. 133.—An adult caddice-fly. (*From Kellogg's "American Insects," after Needham.*)

or streams. They feed on small animal life or bits of vegetation and are among the commonest of insects in the water. The cases are very curious, variable, and characteristic for the species. They are lined with silk and more or less open at each end; in shape cylindrical, ovoid, or spiral, and covered with pebbles, sticks, or pieces of leaves, or tiny snail shells. A few kinds make miniature "fish-nets," which are constructed in swift-flowing water and which strain out small particles of food from the current.

Medium-sized insects with four, similar, membranous wings clothed with rather long hairs, the hind pair usually shorter and broader. Mouth parts modified from chewing type by reduction, the mandibles being absent, but the palps well developed. Antennæ long, setaceous; legs long, tarsi five-segmented, tibiæ with spurs. Metamorphosis complete; larvæ and pupæ aquatic, living in cases and breathing by abdominal gills. Larvæ with 3 pairs of long thoracic legs and one pair of prolegs on the last segment of the abdomen.

The principal importance of the Trichoptera is as food for fish. Both larvæ and adults are of great value as food for trout. One species is said to be a pest in water-cress beds in England.

ORDER LEPIDOPTERA

Moths, Millers, Butterflies, and Skippers

This is the second largest order of insects, and one of the most destructive. Its members are well marked, both as adults and as larvæ, and scarcely likely to be confused with any other order. Nor are the insects of another order likely to be classed as Lepidoptera by mistake. The

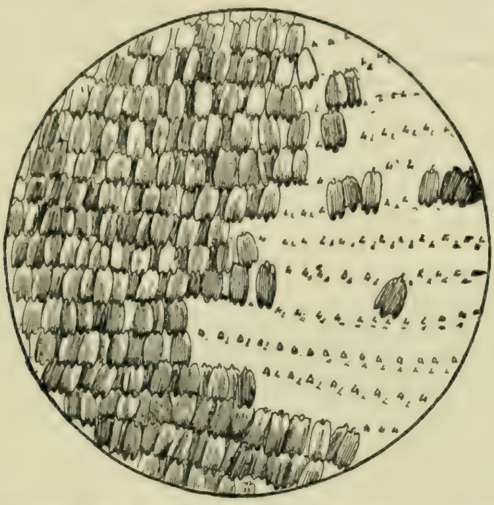

Fig. 134.—A piece of the wing of a butterfly, *Danaus archippus* Fab., showing how the scales overlap at sides and ends. On the right some of the scales have been removed to show the cup-like pits into which the pedicles of the scales fit. Greatly magnified. (*From Kellogg's "American Insects."*)

name means *scaly-winged* and the most characteristic thing about these insects is the layer of short, flattened, hairs or scales that typically covers both surfaces of the wings and practically all other parts of the body. The scales (Fig. 135) are of many shapes, and one can find almost every

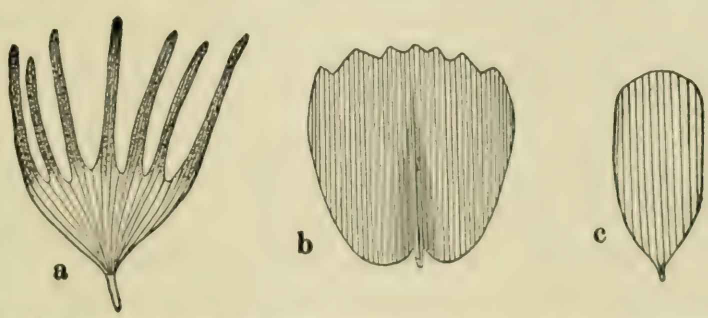

Fig. 135.—Scales from three different species of moths and butterflies. Note the pedicels that fit into cup-like sockets of the wing cuticula and the more or less parallel striæ or ridges. (*From Kellogg's "American Insects."*)

gradation to typical hairs. All of them have a projection or pedicel at one end which fits into a cuplike cavity in the cuticula of the wing membrane. In the lower moths, they are irregularly scattered over the wings; but in the most specialized ones they present a very perfect arrangement, overlapping both on the sides and the ends, like slates or shingles on a roof (Fig. 134).

The function of these scales is primarily to strengthen the wing membrane and make it stiff enough for rapid flight. In some other orders, this has been accomplished by a great increase in the number of veins. In the Lepidoptera, there are not many veins, but the scales on both surfaces of the wing-membranes give them sufficient rigidity for flight. The swiftest-flying moths show the most perfect arrangement of the scales, and the parts of the wing where greatest stress comes have them arranged most regularly.

In addition to strengthening the wing membrane, the scales give protection to most parts of the body, and in them is resident the colors for which moths and butterflies are justly celebrated. If the "dust" (scales) is rubbed from the wings of a moth or butterfly, its characteristic

FIG. 136.—A swift-flying hawk moth, *Theretra tersa* Linné, natural size. (*From Illinois State Nat. Hist. Sur.*)

color is lost. The scales are often ornamented with longitudinal ridges or striæ, which may occur as closely as 35,000 ridges to the inch. They are very regular, and many of the brilliant colors of these insects are produced by the diffraction of light rays by the striæ, rather than by pigments.

Aside from the possession of these scales, the wings of Lepidoptera are not highly specialized (Fig. 48). They are usually very broad, and subtriangular in outline, the front pair somewhat larger. They are often too large to be very effective in flight, since they cannot be flapped up and down rapidly enough. In general we note that the swiftest-flying insects are those with small wings, and, in this order, the swift-flying ones are such as have rather narrow wings; for example, the hawk moths (Fig. 136) and clear winged moths (Fig. 397).

The most highly specialized thing about the Lepidoptera is the mouth parts of the adults. These are probably the most highly specialized of all insect mouth parts. We find as we examine the head (Fig. 71) a pair of very hairy or scaly palps (the labial palps) projecting forward at the sides of the mouth. Between them arises a long slender tube for sucking up liquid foods. The exact length of it is correlated with the kind of flowers the particular moth or butterfly visits. It is often longer

than the body, and in a number of cases measures 5 or 6 inches. Its real make-up is evident from a cross-section (Fig. 71, *B*). From the figure it can be seen that it is double in nature, each half having a groove along its inner (mesal) face, and the two halves are so closely locked together that they form an airtight tube up which exposed liquids can be drawn by suction. This is called the *siphoning type* of mouth parts (p. 126). When not in use, this tube is carried coiled up like a watch spring, so closely beneath the head that it is inconspicuous. Some moths take no food during the adult stage, and in these cases the tube is wanting.

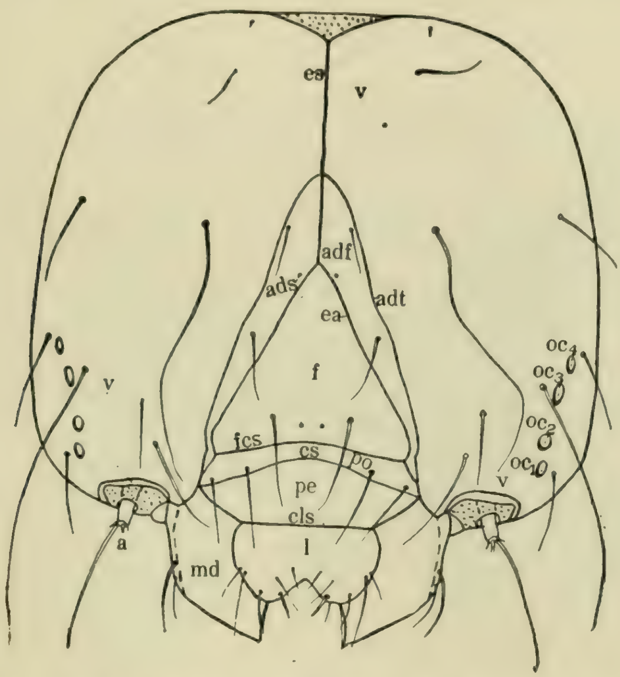

Fig. 137.—The head of the army worm, larva. *an*, antenna; *adf*, adfrontal sclerite; *adt*, adfrontal suture; *cls*, clypeo-labral suture; *cs*, clypeal suture; *ea*, epicranial arm; *es*, epicranial stem; *f*, front; *fcs*, fronto-clypeal suture; *l*, labrum; *md*, mandible; oc_1 to oc_4, ocelli; *pe* and *po*, the clypeus; *v*, vertex. (*Adapted from Ripley, Ill. Biol. Mono., Vol.* VIII.)

It must be emphasized that this proboscis is not a *piercing* structure. It is too flexible to be thrust into plant or animal tissues. This means that these insects must satisfy themselves with liquids freely offered them by other organisms. They have become adapted to taking a very special type of food—the nectar concealed in open cups in the corollas of flowers, particularly those too deep to be reached by other kinds of insects. It is said that an African moth was once taken with a proboscis measuring 10 inches in length. From this a biologist predicted that a flower would be found with a corolla 10 inches deep, and this was subsequently found. The removal of this nectar does not injure the plant; in fact it usually benefits by the visits of these insects to its flowers, since in this way cross-pollination is generally brought about.

In rare cases, the tip of the proboscis is provided with stiff spines, sharp enough to lacerate the skin of a ripe fruit. Thus cotton leafworms

(Fig. 272) develop only on cotton, but in late summer the adults sometimes fly northward in great swarms, at least as far as Lake Erie. If they alight in orchards of ripe peaches, they may do much damage by puncturing the fruits with their "tongues." This is very exceptional, however, and usually moths and butterflies can do no injury in the adult stage. When we speak of an injurious moth, like the clothes moth or the gipsy moth, we refer to the injury caused by the larva or caterpillar of that species. The economic importance of the Lepidoptera arises almost entirely from the activities of the larvæ. This simplifies the problem of control somewhat, as compared with beetles, for example, since only one injurious stage need be considered.

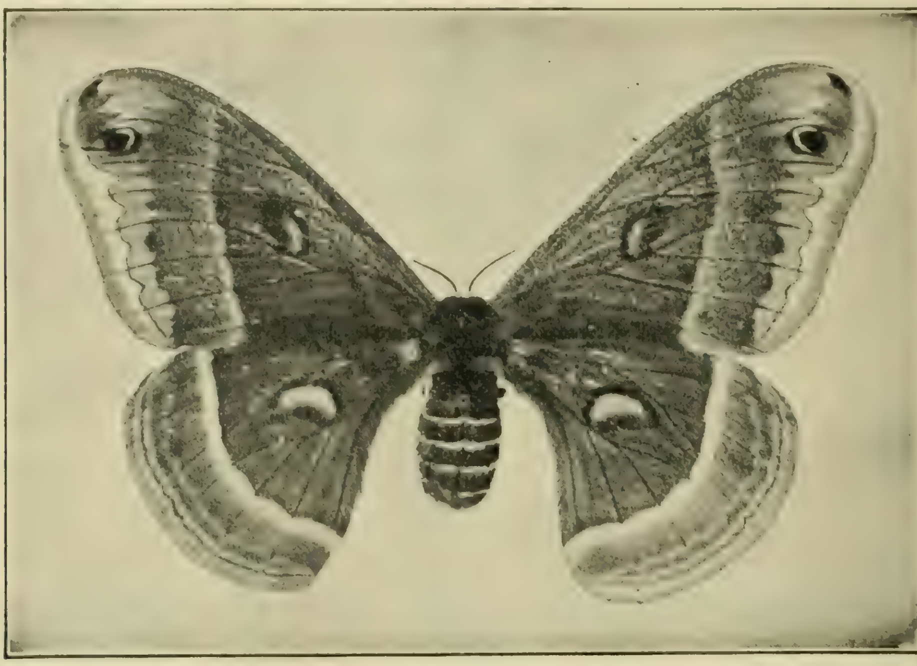

FIG. 138.—The cecropia moth (*Samia cecropia* Linné), a common and beautiful giant silkworm moth. (*From Fernald's, "Applied Entomology."*)

The larvæ of Lepidoptera are called caterpillars, and very often "worms." They have chewing mouth parts and are among the world's greatest pests. They are remarkably similar in structure among the thousands of kinds known. The shape is generally nearly cylindrical (see Figs. 54 and 262). The body is composed of 13 segments besides the head. The first three, or thoracic, segments have each a pair of jointed legs, terminating in a single claw. The abdominal segments bear unjointed, soft, fleshy projections of the body called prolegs, typically one pair each on the third, fourth, fifth, sixth, and tenth segments of the abdomen. Frequently some of these pairs and, in some cases, all of the prolegs are wanting (Fig. 359). Insects of several other orders have larvæ with prolegs, but these are the only insects that have the prolegs armed with a number of fine hooks known as *crochets* (Fig. 54, *4*). These crochets,

which enable the insect to hold on so tenaciously to a leaf or twig, are arranged in circles or rows across the apex of the proleg.

The head of a caterpillar is usually well developed (Figs. 54 and 137). There is a group of simple eyes at each side of the head (Fig. 137, *oc*$_1$ to *oc*$_4$), the number varying from two to six pairs. The antennæ are very small. A very characteristic thing about the larvæ of this order is the presence in at least the last instar, of the *adfrontal areas* (*adf*), slender sclerites bordering the epicranial suture (*es*, *ea*), that do not occur in insects of other orders. Another characteristic of Lepidopterous larvæ is the presence, near the end of the labium, of the spinneret from which the silk exudes.

The pupæ of moths are typically enwrapped in a silken case, called a *cocoon*, which is made from saliva secreted by the full-grown caterpillar (see Fig. 85, *A*, *E*, *I*). Some of them lie buried in the soil, and a few

FIG. 139.—A skipper butterfly (*Epargyreus tityrus* Fabricius) natural size. Note the recurved or hooked antennæ that characterize skipper butterflies. (*From Fernald's, "Applied Entomology."*)

are formed in tunnels in wood or in other larval habitats. The pupæ of butterflies are generally naked chrysalids fastened to plants or other supports by a small pad of silk or a girdle (Figs. 84, *C*; 259, *c*). Regardless of the nature of protection, the pupæ of Lepidoptera (Figs. 84, *A*, *B*, *C*, *D*) can be recognized from other orders by these two features: (*a*) the leg cases, antennæ cases, and wing pads are fastened down to the sides of the body and immovable; (*b*) the long maxillæ in the pupa stage appear as two long slender sclerites along the mid-ventral line.

Adult Lepidoptera are minute to large, fragile insects, well characterized by the siphoning mouth parts and overlapping scales found on upper and under sides of the wings and other parts of the body. Both pairs of wings are membranous, usually very broad, the front pair larger, cross-veins few. Metamorphosis complete. The larvæ typically wormlike, with chewing mouth parts; paired spiracles on the principal segments; two to five pairs of prolegs, with crochets, on the abdomen; and adfrontal areas on the head. Pupæ with appendages usually fast to the body wall, often in cocoons.

Among the many pests of crops and stored products, the following should be noted for figures and descriptions of typical species; army worm (p. 318), cutworms (p. 321), European corn borer (p. 333), tomato hornworm (p. 488), swallowtail butterfly (p. 510), cabbage butterfly (p. 495), fall webworm (p. 564), gypsy moth (p. 690), peach-tree borer (p. 595), greenhouse leaftyer (p. 714), clothes moths (p. 748), and flour and meal moths (pp. 758 to 761).

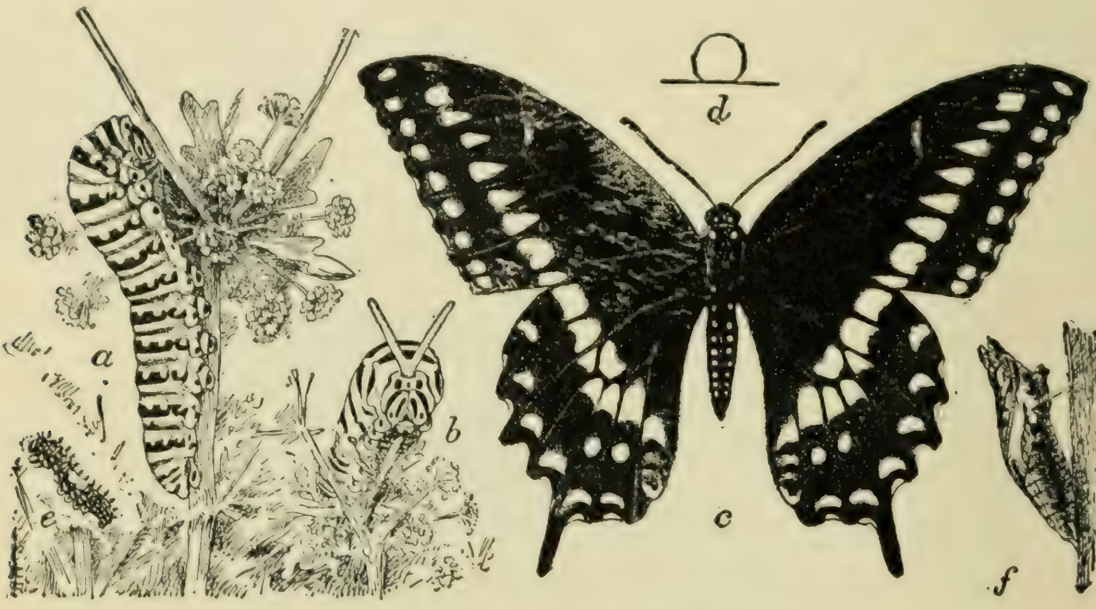

FIG. 140.—The celery caterpillar or black swallow-tail butterfly (*Papilio polyxenes* Fabricius) and its life-stages. *a*, full grown caterpillar from the side; *b*, the same from in front showing osmateria protruded; *c*, the male butterfly, note clubbed antennæ; *d*, outline of the egg greatly enlarged; *e*, a young larva; *f*, the pupa or chrysalis. All about natural size except *d*. (*From U. S. D. A. Farmers' Bull.* 856.)

For our purposes, probably the most useful division of the order is the popular one into moths and butterflies. The principal families of each suborder are outlined in the following:

SYNOPSIS OF THE LEPIDOPTERA

A. **Suborder** *Heterocera.*—Moths or Millers. Mostly night fliers. Antennæ of varied form, filiform, pectinate or otherwise, but never enlarged at the tip to form a club. Abdomen heavy. Wings usually lie horizontally or rooflike at sides of abdomen or wrapped around abdomen when at rest. When in flight, wings of same side held together, usually, by long curved bristle or group of bristles attached near base of hind wing and known as a *frenulum.* Often have two ocelli. Pupæ very often protected by cocoons.

Family 1. Carpenter moths, Family Cossidæ
Family 2. Slug-caterpillar moths, Family Eucleidæ
Family 3. Leaf miners, clothes moths, etc., Family Tineidæ
Family 4. Bagworm moths, Family Psychidæ
Family 5. Gelechiid moths, Family Gelechiidæ
Family 6. Plutellid moths, Family Plutellidæ

Family 7. Clear-winged moths, Family Ægeriidæ (Sesiidæ)
Family 8. Leaf-roller moths, Family Tortricidæ
Family 9. Pyralid moths, Family Pyralididæ
Family 10. Hawk moths or sphinx moths, Family Sphingidæ
Family 11. Measuring-worm moths, Family Geometridæ
Family 12. Prominents, Family Notodontidæ
Family 13. Tussock moths, Family Lymantriidæ
Family 14. Owlet moths, Family Noctuidæ
Family 15. Tiger moths, Family Arctiidæ
Family 16. Royal moths, Family Citheroniidæ
Family 17. Giant silkworm moths, Family Saturniidæ
Family 18. Silkworm moths, Family Bombycidæ
Family 19. Tent caterpillars and others, Family Lasiocampidæ

B. Suborder *Rhopalocera.*—Butterflies and Skippers. Dayfliers. Antennæ clubbed or enlarged near the tip. Wings usually held vertically above the body when at rest with the upper surfaces of the two pairs in contact. When in flight, wings of the same side are held together usually by an expansion of the membrane of the hind wing near its base which is known as a *jugum.* No ocelli.

1. *The Skippers.*—Abdomen heavy. Antennæ with a recurved hook at the tip, their bases wide apart. Larvæ with a distinct necklike constriction just behind the head.

   Family 20. The Common Skippers, Family Hesperiidæ (Fig. 139)

2. *The Butterflies.*—Abdomen slender. Antennæ without a recurved hook on the terminal club, their bases inserted close together. Pupæ never protected by cocoons.

   Family 21. Swallowtails, Family Papilionidæ (Fig. 140)
   Family 22. White and sulfur butterflies, Family Pieridæ
   Family 23. Four-footed butterflies, Family Nymphalidæ
   Family 24. Hair-streaks or gossamer wings, Family Lycænidæ

ORDER HYMENOPTERA

Bees, Wasps, Ants, Sawflies, Parasites, and Others

Everyone knows at least three kinds of Hymenoptera—bees, wasps, and ants. But not only are there numerous families of bees, wasps and ants, but in addition to them, the order includes a much greater number of species of other habits, such as the parasitic wasps, the gall wasps, and the sawflies, which are fully as important to us and altogether as interesting as the better-known kinds, but which are not well known.

This order is listed as third in point of size (see Table VI, p. 171), but it has been so little studied in comparison with the beetles or moths and butterflies that it would not be surprising to see it surpass these orders, when its unnumbered species are once thoroughly studied.

Most authors place the Hymenoptera at the top of the list of orders, in much the same way that man is placed at the pinnacle of the vertebrate animals; and for much the same reason. This order appears to exhibit instinctive behavior in its highest state of perfection. In some of its representatives is found at least a low grade of intelligence; that is, the ability to learn, or profit by experience.

As a basis for the social organization which is so elaborately perfected in the better-known Hymenoptera, we note that *care of the young* is

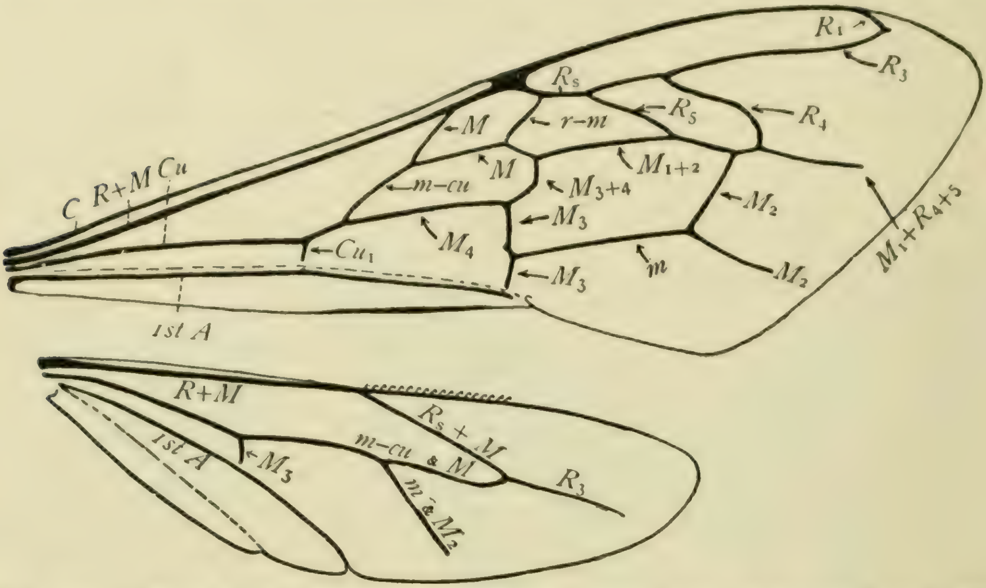

FIG. 141.—Wings of the honeybee showing the minute hooks or hamuli that serve to lock the two wings together. (*From Comstock's "Introduction to Entomology," Comstock Publishing Co.*)

widespread and often solicitous, in contrast with most insects which ordinarily pay no attention to their young after the eggs are laid. The larvæ of many groups of this order are completely dependent upon their parents (or other adults) for food. Among the parasitic and gall-making species this obligation is discharged by the females when they lay their eggs in the midst of an abundance of food. The solitary wasps and bees generally gather and store a quantity of food of a suitable kind, available to the larvæ in the nest when they hatch from the egg. But the social wasps and bees, and the ants, bring food to the larvæ day by day, during their entire lives, and often feed, clean, guard, and care for the young in a manner suggestive of the maternal care that is general among the higher vertebrate animals. All of the ants and many of the wasps and bees live together in great colonies, leading a complex social or cooperative life, the wonders of which increase the more intimately man exposes their details to common knowledge.

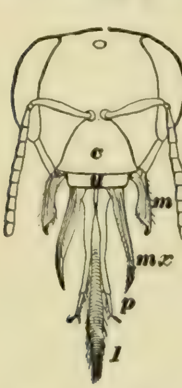

FIG. 142.—Head of a honeybee showing chewing-lapping mouth parts from in front. *a*, antenna; *c*, clypeus; *u*, labrum; *m*, mandible; *mx*, maxilla; *p*, labial palp; *l*, labium. (*From Comstock's "Introduction to Entomology." Comstock Publishing Co.*)

The social life of the Hymenoptera is rivaled by that of the termites already described. As in that case, the reproductive function is limited to a few specialized individuals (kings and queens), while the vast majority of the adults remain infertile. These barren individuals work, not

for themselves, but for the common good, building and cleaning the nests, foraging for food, fighting off invaders, and taking complete care of the prodigious number of young that hatch from eggs laid by the queens. In contrast with the termites, the workers and soldiers of the Hymenoptera, when these castes are developed, are *exclusively females.* The males accordingly have earned the name *drones*, their sole usefulness to the species apparently being to insure the fertility of the queen's eggs.

The unusual mental development of the higher Hymenoptera is a strong reason for listing this order as the most specialized. But it should

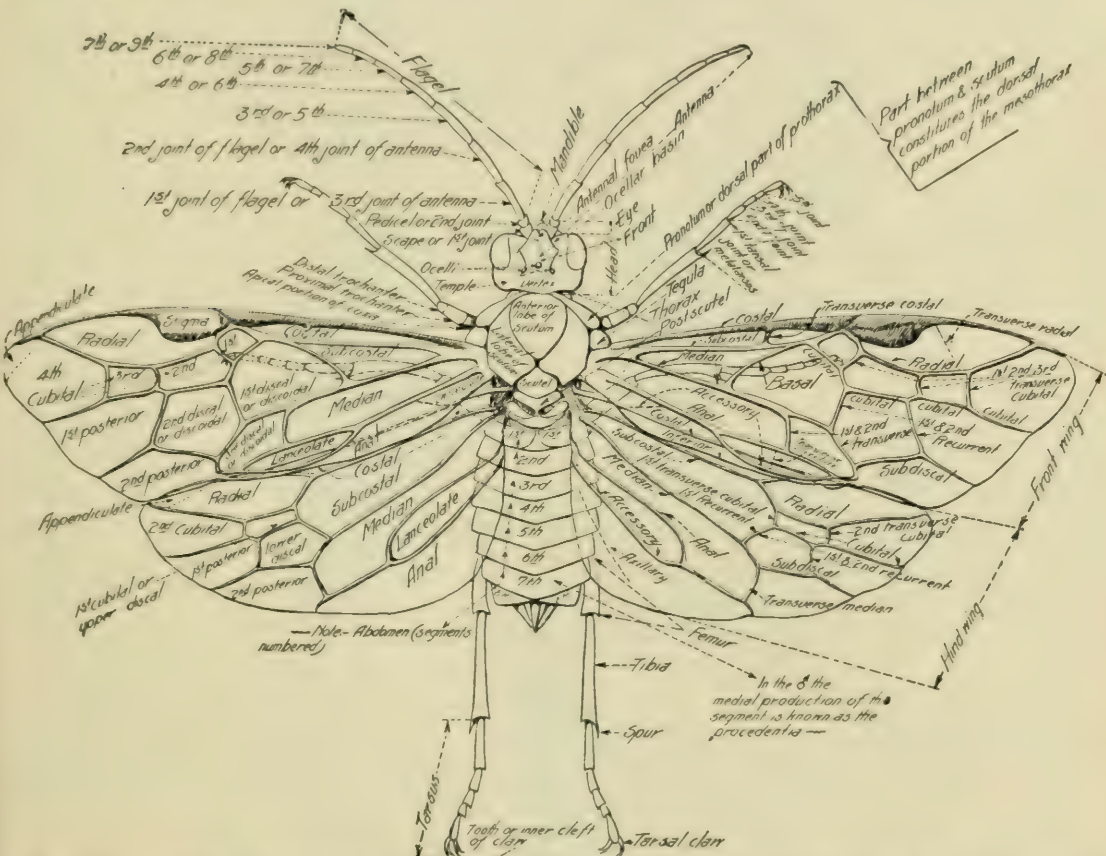

FIG. 143.—Dorsal view of a sawfly to show names of the principal parts of the body which are used in classification. (*From Conn. State Geol. and Nat. Hist. Sur. Bull.* 22.)

be considered as only one criterion and not be allowed to overshadow other considerations. In the matter of wing specialization, the Hymenoptera are surpassed by the Diptera or the Coleoptera and possibly by the Lepidoptera and Hemiptera. In the specialization of the mouth parts, the Diptera, Siphonaptera, Anoplura, Hemiptera, Homoptera, and especially the Lepidoptera, have gone much farther. These are some of the reasons we have for giving the Hymenoptera in our series a middle ground among insects with a complete metamorphosis.

The Hymenoptera have a complete or complex metamorphosis. The larvæ of this order vary much more in form than those of the beetles or moths, ranging from caterpillar-like sawflies, with distinct head, well-

developed legs and prolegs, and independent active habits, to the legless and practically helpless progeny of bees, wasps, and ants. The sawfly larvæ (Fig. 83, *A*) can be distinguished from caterpillars (Lepidopterous larvæ), which they most resemble, by the number of prolegs, which is from six to eight pairs, whereas Lepidopterous larvæ (Fig. 54) never have more than five pairs; also the prolegs are not provided with crochets like

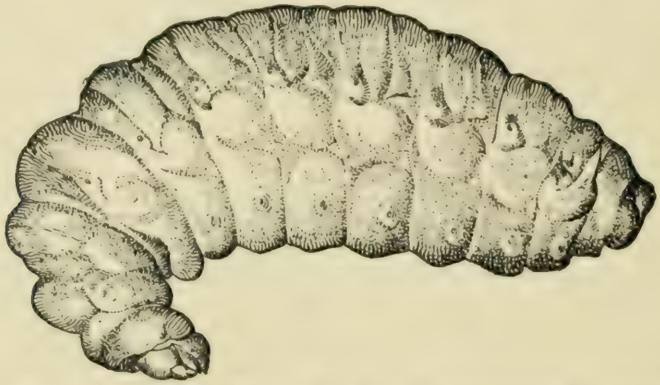

FIG. 144.—Larva of a digger wasp, *Tiphia* sp., note reduced head, spiracles on the sides of the body, and absence of legs. (*From Ill. State Nat. Hist. Sur.*)

those of Lepidoptera; the adfrontal sclerites are never present in Hymenoptera; and the ocelli are at most one pair in Hymenoptera, always more than one pair in Lepidopterous larvæ. The more specialized larvæ (Fig. 144) differ from Dipterous larvæ, with which they are most likely to be confused, in having a recognizable head (although it may be reduced in

FIG. 145.—One of the horntails, the pigeon tremex, *Tremex columba* (Linné), natural size. (*From Kellogg's "American Insects," after Jordan and Kellogg.*)

size), with distinct mouth parts. Also, in contrast with most Diptera, the larvæ usually have a pair of spiracles on each of the principal abdominal segments, and not a large complex pair close together on the last segment. The antennæ are usually wanting, and the ocelli wanting or a single pair. In the higher families the head of the larva is opaque white like the rest of the body.

The pupæ (Figs. 84, *K*, *M* and 85, *M*) resemble beetle pupæ in having the appendages not immovably fastened to the general body wall. The antennæ of the pupa are always longer than the head, and the mandibles can be recognized as of the chewing type. The labium and maxillæ are elongate, the compound eyes show distinctly, and the pupa is generally surrounded by a silken cocoon. In some of the Hymenoptera, the metamorphosis is complicated by *polyembryony*, the name given to the remarkable condition in which anywhere from 2 to over 150 individuals develop from a single egg by the splitting up of the egg at an early stage of development into a number of embryos. The life cycle may be further complicated by *parthenogenesis* and an *alternation of generations*. In some species a given generation may be all females; these lay unfertilized eggs on a kind

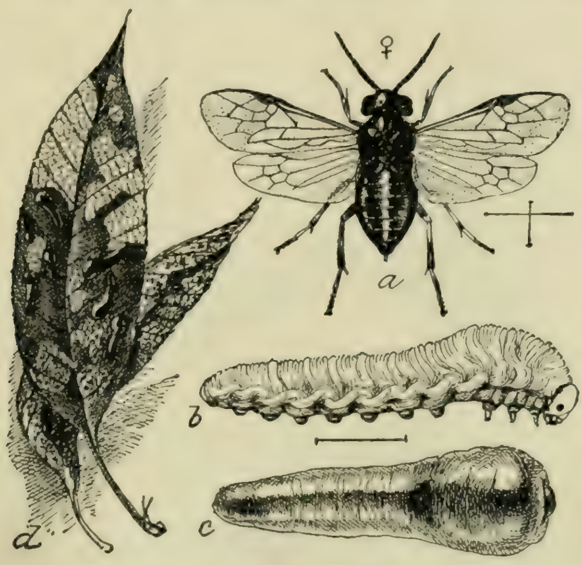

FIG. 146.—The pear slug, *Caliroa cerasi* Linné. *a*, adult female sawfly; *b*, larva with slime removed, side view; *c*, slime-covered larva, dorsal view; *d*, leaves being skeletonized by the larvæ, natural size. Natural size of *a*, *b*, and *c* is indicated by the lines. (*From Sanderson and Jackson, "Elementary Entomology, after U. S. D. A.*)

of plant, say an oak, and a characteristic gall grows on the plant to shelter the insect. When this generation of insects is mature they may be of both sexes, and the females lay fertilized eggs on another kind of plant, for example a rose. As a result, the rose develops a gall altogether different in appearance from that of its parents on oak. When these young are mature, all prove to be parthenogentic females that seek the oak again and produce galls like those in which their grandparents developed. Until such species are carefully watched through several generations, they are sure to be described as two distinct species, so different are they both in habitat and in appearance.

The wings in this order (Fig. 141) are four in number. They are generally small, transparent, and with comparatively few veins. The front pair is distinctly larger. The hind wing usually fits exactly against the hind margin of the front wing, to which it is fastened by a row of very

minute hooks. The student should note this carefully, otherwise he may mistake certain ones of this order for Diptera, since the two pairs of wings are so closely fitted together as easily to be mistaken for a single pair.

The mouth parts vary from the chewing type to a combination of chewing and lapping structures (Fig. 142). In all cases the labrum and the mandibles are essentially like those of Orthoptera and Coleoptera. The maxillæ and labium are also essentially of the chewing type in the less specialized families, but in the bees, wasps, and ants, these two paired

FIG. 147.—A wasp, *Lysiphlebus testaceipes* (Cresson), depositing its eggs in the body of the alfalfa aphid, much enlarged. (*From Essig's "Insects of Western North America," copyright*, 1926, *by The Macmillan Company. Reprinted by permission.*)

structures become progressively longer and longer, to form a hairy, lapping tongue which makes a food channel up which liquids flow as the insect feeds (see p. 126 and Fig. 72).

One specialization peculiar to the Hymenoptera is the modification of the ovipositor into a defensive and offensive organ known as a "stinger." This organ of defense and offense is found only among the insects of the order Hymenoptera—the bees, many of the wasps and certain kinds of ants, besides the distantly related scorpions.

The stinger of a bee or wasp is a very complex and beautifully adapted organ. It is known to be the equivalent (homologue) of the egg-laying organ in other insects and it follows therefore that *only the females of insects*

can sting. In many of the Hymenoptera (Fig. 40), a greatly elongated, stinglike organ serves the function of thrusting eggs into plant parts but is never used in defense. The stinger consists of a similar mechanism for penetrating the skin to a depth of perhaps $\frac{1}{10}$ inch and of a system of glands to secrete the venom that is injected into the wound. In the honeybee, the sting proper consists of two extremely sharp, highly

FIG. 148.—A sphecid wasp, *Ammophila* sp. putting a paralyzed measuring worm into her burrow to serve as food for her young. When the nest is completed and the eggs laid, the wasp takes a small pebble in her mandibles and packs down the earth with which she closes her burrow. (*From Kellogg's "American Insects."*)

polished brown spears or darts which appear as one. Their concave inner surfaces make, between them, a fine tube down which the venom is forced to emerge at their tips. As the insect stings, these two darts are alternately and very rapidly thrust in and out on guide rails of a surrounding sheath. Each dart has near its tip 9 or 10 recurved hooks

FIG. 149.—A mud-dauber, *Sceliphron cementarius* (Drury). (*From Sanderson and Jackson "Elementary Entomology" after S. J. Hunter.*)

FIG. 150.—The bald-faced hornet, *Vespa maculata* Kirby, about natural size. (*From Sanderson and Jackson," Elementary Entomology."*)

which hold it firmly until the next thrust carries it still deeper. Because of these hooks, the honeybee can seldom remove her stinger, and it, with more or less of the viscera, is torn away as she escapes. Other bees, wasps, hornets, and ants may sting repeatedly.

The pain of the sting is due to the venom. In some of the Hymenoptera this vemon is deadly to other insects and small animals receiving

it. In others it has only a paralyzing effect and is used to stupefy flies, spiders, crickets, caterpillars, or beetles upon which eggs are laid and the helpless plunder is then sealed up in their nests as food for the forthcoming young (Fig. 148).

Another peculiarity of the adults of this order is that one abdominal segment is fused with the thoracic mass, so that what appears to be the first abdominal segment is in reality the second.

Wings typically four, small, membranous, with few veins; hind wings smaller, often hooked to front pair Mouth parts chewing or chewing and

FIG. 151.—Paper nest of the bald-faced hornet, *Vespa maculata* Kirby, actual size 10 to 15 inches in diameter. (*From Kellogg's "American Insects."*)

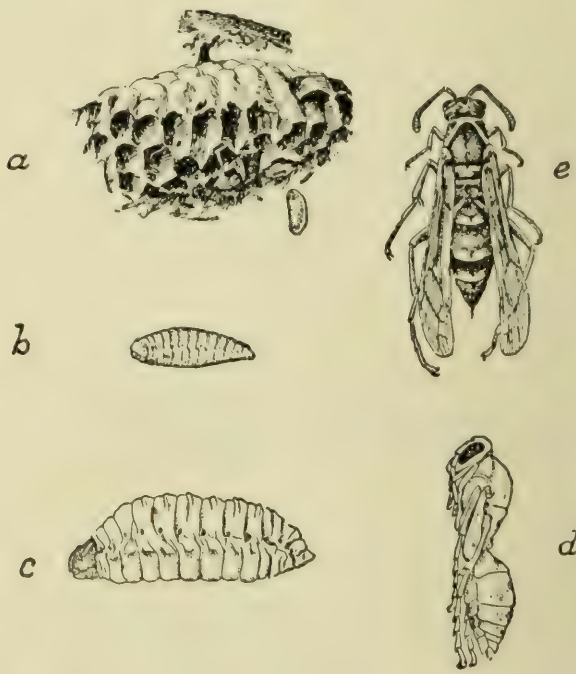

FIG. 152.—A paper-nest wasp, *Polistes* sp.; *a*, nest and egg; *b*, young larva; *c*, older larva; *d*, pupa; *e*, adult. All enlarged one-half, except nest, which is reduced. (*From Kellogg's "American Insects."*)

lapping. Abdomen often with a slender waist and its first segment united with the thorax. Female provided with an ovipositor or stinger. Metamorphosis complete. Larva either caterpillar-like or legless, with distinct head, and spiracles on the principal segments. Prolegs, when present, usually more than five pairs and without crochets. No adfrontal areas. Pupæ with appendages free, commonly encased in cocoons. Many species live in societies.

The destructive species are comparatively few, the following being the best known: wheat jointworm (p. 374), pear slug (p. 616), sawflies (p. 663), currant worm (p. 633), corn field ant (p. 315), house ants (p. 734).

The classification of the Hymenoptera appears to be in a very unsettled condition. The following outline will indicate the principal

families and something of their natural grouping. We have followed Comstock's[1] account in many respects but have varied from the opinions of specialists, where by so doing it seemed possible to give the non-technical student a more useful working conception of these insects.

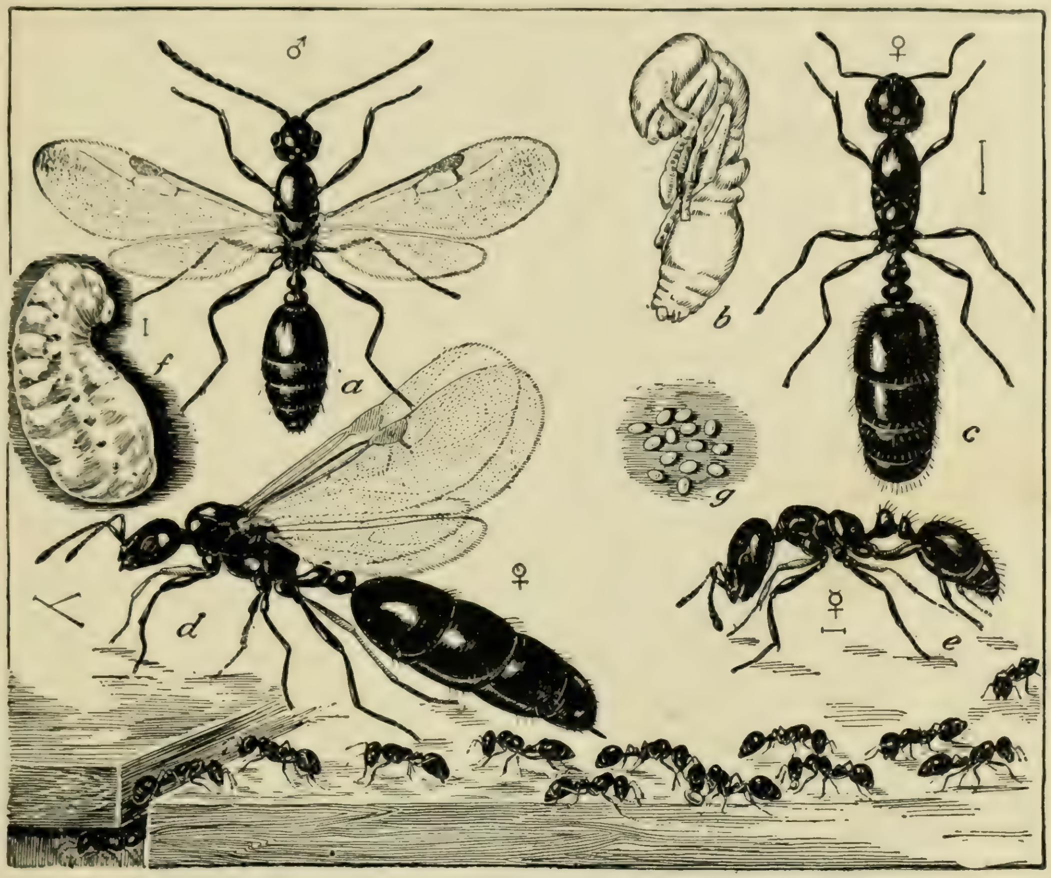

FIG. 153.—The little black ant, *Monomorium minimum* Buckley; *a*, male; *b*, pupa; *c*; female after losing wings; *d*, winged female; *e*, a sterile female or worker; *f*, larva; *g*, eggs. below, a group of workers in line of march. The lines indicate natural size. (*From Marlatt, U. S. D. A. Farmers' Bull.* 740.)

A SYNOPSIS OF THE HYMENOPTERA

A. Suborder *Chalastogastra, Symphyta, or Sessiliventres.*—Foremost segments of abdomen as broad as the following segments and joined to the thorax by their full width (*i.e.*, without a slender waist). The larvæ feed on or in plants and are caterpillar-like in appearance.

Family 1. The horntails, Family Siricidæ (Fig. 145).
Family 2. The stem sawflies, Family Cephidæ.
Family 3. The sawflies, Family Tenthredinidæ (Figs. 143, 146).

B. Suborder *Clistogastra, Apocrita, or Petiolata.*—First segments of abdomen narrower than those which follow, making the connection to the thorax a slender petiole or "waist." The larvæ are of varied habits, always legless and grublike, with head and mouth parts reduced, antennæ and palps at most of one segment, and ocelli usually wanting.

[1] COMSTOCK, "An Introduction to Entomology," The Comstock Publishing Company, 1924.

Wasps or Wasplike Forms

Hairs of body not branched. First segment of hind tarsus usually cylindrical. No tubercles on petiole of abdomen.

(*a*) *Solitary species consisting of only males and females;* each female provides for her own young.

1. Larvæ mostly parasitic on other insects. Eggs generally laid through the body wall of the host.
    - Family 4. Ichneumon wasps, Family Ichneumonidæ (Fig. 40)
    - Family 5. Braconid wasps, Family Braconidæ (Fig. 147)
    - Family 6. Ensign wasps, Family Evaniidæ
    - Family 7. Chalcid wasps, Family Chalcididæ (see Fig. 39)
    - Family 8. Egg-parasite wasps, Family Scelionidæ (see Fig. 38)
2. Larvæ mostly live in galls which they cause to grow on plants (see Fig. 4).
    - Family 9. Gall wasps, Family Cynipidæ
3. Larvæ mostly parasitic on other insects or spiders. Eggs laid on paralyzed ("stung") caterpillars, grubs, or spiders, which are buried in the ground or stored in mud cells, burrows, tunnels, mines or natural cavities; or on active leafhoppers, etc.; or in nests of other Hymenoptera. Or rarely food is brought to larvæ in the nest from day to day, by the parent wasps.
    - Family 10. Digger wasps, mud-daubers, and thread-waisted wasps, Family Sphecidæ (Figs. 148, 149).
    - Family 11. Dryinid wasps, Family Dryinidæ
    - Family 12. Spider wasps, Family Pompilidæ
    - Family 13. Cuckoo wasps, Family Chrysididæ
    - Family 14. Velvet "ants," Family Mutillidæ
    - Family 15. Vespoid digger wasps, Family Scoliidæ
    - Family 16. Mud wasps, Family Eumenidæ

(*b*) *Social wasps with a sterile worker caste in addition to both males and females;* the workers taking most care of the females' young. Eggs laid in cells of nests composed of paper, which the adults make of wood. Larvæ are fed from day to day on juices of insects or sweets. Wings folded lengthwise when at rest.

- Family 17. Hornets, yellow jackets and paper-nest wasps, Family Vespidæ (Figs. 150, 151, 152)

Ants

Hairs of body not branched. Petiole of abdomen with one or two swellings or tubercles (Fig. 495). Often wingless. Social insects with a sterile worker caste, in addition to males and females. Nests in soil, wood or stems of plants, without well-defined cells for each larva to live in. Larvæ fed on regurgitated food from adults, or on bits of insects, seeds, fungi, etc.

- Family 18. Ants, Family Formicidæ (Fig. 153)

Bees

Hairs of thorax branched or plumose (Fig. 155). First segment of hind tarsus often broad, flattened and brushlike for assembling pollen, and hind tibiæ often specialized as a "pollen-basket" (Fig. 47, *C*). Nests provisioned with nectar and pollen from flowers, as food for the young.

(*a*) *Solitary bees consisting of only males and females.*

1. Tongues (labia) short and broad. Eggs laid in nests burrowed in ground, in pithy plants, or in crevices of walls or buildings. Cells separated by a silky secretion.
    - Family 19. Bifid-tongued bees, Family Prosopidæ
    - Family 20. Colletids, Family Colletidæ

2. Tongues long and slender (Fig. 142).
   i. Nests in burrows in plant stems, in cavities about buildings or in the soil. Eggs laid in cells made of pieces of leaves cut from growing plants, or of plant fibers. Pollen-collecting brushes on under side of abdomen of females.
   Family 21. Leaf-cutting bees, Family Megachilidæ
   ii. Nests in tunnels cut in the solid wood of buildings or trees. Eggs laid in cells separated by cemented sawdust.
   Family 22. Large carpenter bees, Family Xylocopidæ
   iii. Nests in tunnels in pithy plants. Cells separated by plugs of plant fiber.
   Family 23. Small carpenter bees, Family Ceratinidæ

(*b*) *Parasitic or "cuckoo" bees* that lay their eggs in nests of other bees and so steal the food or parasitize the rightful owners. Tongues long. Legs not adapted for collecting pollen. Males and females only, no worker caste.
Family 24. Cuckoo bees, Family Nomadidæ

(*c*) *Gregarious bees consisting of only males and females.* Nests placed near together in the soil or in the face of cliffs, often with a common entrance or corridor. Tongues short or long and pointed.
Family 25. Mining bees, Family Andrenidæ (Halictidæ)
Family 26. Anthophorids, Family Anthophoridæ

(*d*) *Social bees, with a worker caste* in addition to males and functional females. Eggs laid in cells made of wax secreted by worker bees (see Fig. 23).
1. Nests commonly in deserted mouse nests on the ground (Fig. 154). A number of eggs usually laid together in one waxen cell.
   Family 27. Bumblebees, Family Bombidæ (Bremidæ) (Fig. 26).
2. Nests built in trees or in hives provided by man. A single egg laid in each cell (Fig. 22).
   Family 28. Honeybees, Family Apidæ

FIG. 154.—Nest of a bumblebee, *Bombus auricomus* Robertson, in a deserted mouse nest. Note *A*, the wax-pollen lining material for protection of the nest; *B*, four empty cocoons from which adult bees have emerged and which are used later for the storage of honey and pollen; *C*, a wax-pollen mass enclosing eggs; *D*, cocoons containing larvæ, pupæ or adult bees not yet emerged; and *E*, the remnants of the old mouse nest below. (*From photo by T. H. Frison.*)

As a group, the Hymenoptera may be considered more beneficial than injurious. There are to be sure a number of serious pests. But the work of the very many insect parasites and predators, the activities of the bees in pollinizing plants, and the production of honey and wax, undoubtedly offset the injury inflicted by members of this order, manyfold.

Fig. 155.—Branched, plumose and threaded hairs, showing a characteristic of bees. *a* to *f* are from bumblebees; *g* to *j* of *Melissodes* sp.; *k* to *o* of the leaf-cutting bee, *Megachile* sp. (*From Comstock's "Introduction to Entomology" after J. B. Smith.*)

ORDER SIPHONAPTERA

The Fleas

This is a very small order, very well defined, and not closely related to any other group of insects. All of the species are wingless and all are, in the adult stage, external parasites on warm-blooded vertebrates. They are almost unique among insects in being flattened, or thin, from side to side, like a sunfish. The legs are long, adapted for jumping, and the coxæ are abnormally large, often being actually the largest segment of the leg (Fig. 555).

The body wall is hard or tough, polished, and provided with many backwardly directed hairs and with short, stout spines, often arranged so regularly as to resemble combs.

There are no compound eyes and often the simple eyes also are wanting. The three-segmented antennæ are concealed in grooves just behind the eyes (see Fig. 67, *A*).

The mouth parts (Fig. 67) are piercing-sucking in type, but differ from any of the other subtypes in having the labium divided into two segmented parts (palps?). The mandibles and labrum-epipharynx are

adapted as stylets for piercing and forming the salivary duct and food channel, but the maxillæ are broad, triangular plates that do not enter the wound but do bear segmented palps. Another unusual feature of the fleas is that the three segments of the thorax are very distinct and free from each other.

These are almost the only external insect parasites of our larger animals that have a complete metamorphosis. The adult stage is the only stage that is known to people generally. The eggs are not fastened to the host, like the eggs of lice, and so are not noticed. They drop off the host or are laid on the floor of the nest or kennel or dwelling of the host. The larvæ that hatch from the eggs (Fig. 83, *L*) are very slender, cylindrical, whitish maggots with a distinct head, antennæ and mouth parts, but no ocelli and no legs. There are 12 well-marked body segments in addition to the head. There are usually minute paired spiracles on the thoracic and abdominal segments, and each segment bears several very long, stiff hairs. The larvæ, which are very active, live on such dead animal and vegetable matter as they find in the cracks of floors or in the dirt about the sleeping quarters of their hosts. When full-grown they spin a cocoon of silk, covered with particles of dirt, inside of which the pupa is formed. The pupa may be recognized by its compressed body, absence of wings, inconspicuous eyes, antennæ which are shorter than the head, and mandibles elongated for piercing. The appendages of the pupa are free from the body wall (Fig. 84, *J*).

Small, laterally compressed, jumping insects, entirely wingless, usually spiny, and in the adult stage living as external parasites on warm-blooded animals. Compound eyes small or absent; antennæ short, and concealed in grooves; no neck. Mouth parts piercing-sucking, with two pairs of palps. Thoracic segments distinct. Coxæ very large; hind legs fitted for jumping; tarsal segments five. Metamorphosis complete. Larvæ slender, cylindrical, without legs or eyes, but with well-developed head, chewing mouth parts and spiracles on the principal body segments. Pupæ without wings, enclosed in a cocoon.

The only families of much importance are:

The common fleas, Family Pulicidæ

The sticktights or chigoes, Family Echidnophagidæ

The first family is important, not only as a very universal pest of cats, dogs, and hogs, that often infests houses where pets are kept and seriously annoys the persons that live there, by biting them; but also especially as the known carriers of the dread bubonic plague or "black death" (see p. 839). The second family includes the sticktight flea that attaches to the head of chickens, the females remaining fixed in this position sucking the blood; and the true chigoe or jigger,[1] the females of which, after mating, burrow into the flesh of man, especially about

[1] Not to be confused with the chigger mite (see p. 845).

the feet, and, as the eggs develop, increase enormously in size and cause bad sores.

ORDER DIPTERA

Flies, Mosquitoes, Gnats, Midges

The final order of insects on our list is the Diptera. They are a well-marked group in respect to the condition of the wings, and fairly homogeneous in general appearance; but in habits and in most other characteristics the order presents great diversity.

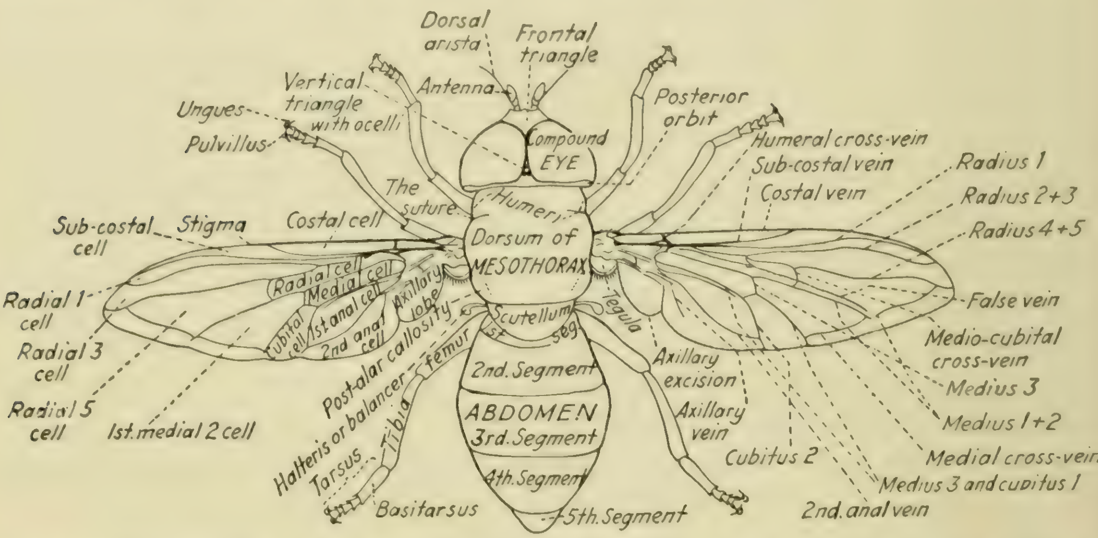

FIG. 156.—Dorsal view of a male syrphid fly to show names of the principal parts of the body.

The following names of veins are used by some authors instead of the ones shown in the figure; *auxiliary* instead of subcostal; 1*st longitudinal* instead of radius 1; 2*nd longitudinal* instead of radius 2 + 3; 3*rd longitudinal* instead of radius 4 + 5; 4*th longitudinal* instead of medius 1 + 2; *anterior cross-vein* instead of medio-cubital cross-vein; *lower cross-vein* instead of medius 3; 5*th longitudinal vein* instead of medius 3 + cubitus 1; *posterior cross-vein* instead of medial cross-vein; *anal cross-vein* instead of cubitus 2; 6*th longitudinal vein* instead of 2nd anal. Also *alula* or *squama* instead of tegula.

The following names of cells are used by some authors instead of the ones shown in the figure: *marginal* instead of radial 1; *submarginal* instead of radial 3; 1*st basal* instead of radial; 1*st posterior* instead of radial 5; 2*nd basal* instead of medial; *discal* instead of 1*st* medial 2; 3*rd posterior* instead of cubital; *anal* instead of 1st anal; *axillary* instead of 2nd anal. (*From Metcalf, in Ohio Biol. Survey Bull.* 1).

They are set apart from all other orders of insects by having a single pair of wings (the front pair) developed for flight, and each of the hind pair reduced to a short, slender thread, with a knob at the end of it (Fig. 156). These rudimentary second wings are called *halteres* or balancers. There is some evidence that they are orienting organs, serving to keep the insects balanced, something like the semicircular canals in the skull of the vertebrates. A few other insects have a single pair of wings, such as certain beetles and May-flies, but these never possess halteres. Many of the Diptera are wingless, having lost the

first pair of wings; but even then the halteres usually remain, so that the possession of halteres is perhaps the most distinctive thing about this order. The front pair of wings is similar to those of bees and wasps in texture; that is, transparent and with comparatively few veins, as a rule. They are small in comparison with the size of the insect, a condition associated with very swift flight. While usually clear, they may have a color pattern (Fig. 163), and sometimes the veins are bordered with scales.

FIG. 157.—A crane fly or tipulid, male, adult. (*From Sanderson, "Insect Pests," after Weed.*)

The three body regions are very distinct in Diptera. The head is large, often hemispherical, and attached to the thorax by a very slender stem or neck. By reason of the fact that only the front wings are functional, the thoracic mass is largely made up of the mesothorax. A small, distinct, semicircular part of the mesothorax overhanging the base of the abdomen is called the *scutellum*. The abdomen is of varied shape, usually shows from four to nine segments, and the cerci, ovipositor, and male genitalia are normally withdrawn, so as to be invisible when at rest.

The mouth parts of adult Diptera are rather varied in form. Two distinct types are represented; the piercing-sucking type and the sponging

type (see pp. 120–126). There are several varieties of the former, called subtypes. (See Figs. 65, 66, and 70.) So far as known, no adult fly masticates solid foods; and few, if any, pierce plants to suck the sap. The majority probably feed upon the nectar and pollen of flowers; many others depend upon liquid organic matter such as that from decomposing plant or animal bodies, flowing sap, and honeydew; or they dissolve solid substances in their saliva (*e.g.*, sugar) and sponge up the solution. A number of species are predaceous on other insects, sucking the juices from their bodies. The females of hundreds of species, representing at least eight families, suck the blood of warm-blooded animals, and, in

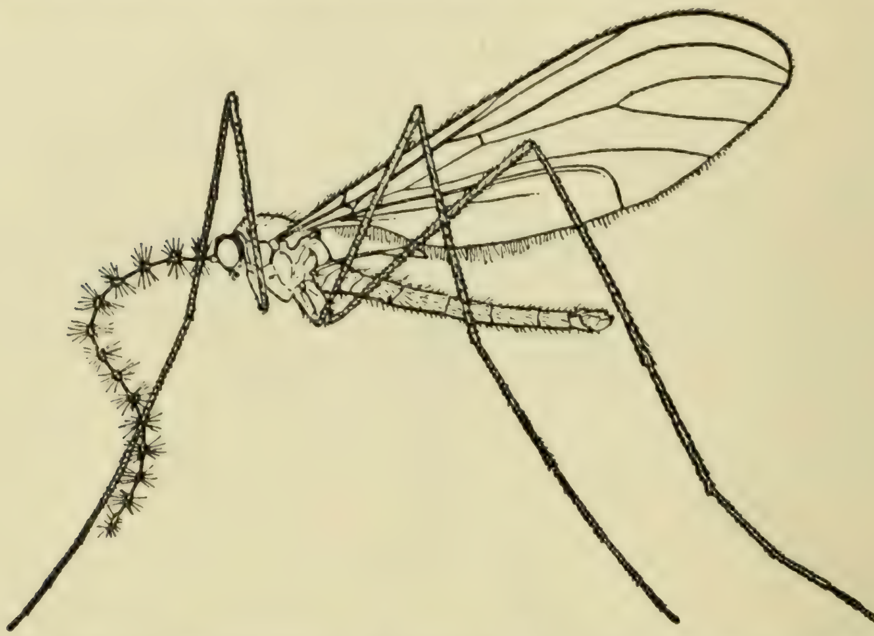

Fig. 158.—A gall gnat, *Hormosomyia oregonensis* Felt, male, side view, much enlarged. (*From Cole and Lovett, "Oregon Diptera."*)

the Muscidæ and Hippoboscidæ, the males also have this bad habit. There are many adults that take no food whatever, this life stage generally being short and occupied almost exclusively with the business of getting the eggs developed, fertilized, and laid.

The metamorphosis is complete or complex. The larvæ are well separated from the adults both structurally and in habits and specialized to a more extreme degree than the larvæ of any other order. There are very few cases where the larvæ and adults live together and partake of the same kind of food, as is so common among the beetles. The larvæ are always legless and in the larger part of the order have no distinct head (Figs. 36, *C* and 83, *J*). In those species where the head is distinct (mosquitoes, for example, (Figs. 83, *E*, *G*, and 548)) the mouth parts of the larvæ are of the chewing type; but in the great majority of species the body tapers gradually to the front end and terminates in a small conical segment which can be protruded or retracted. This head

segment bears no eyes, and no true mouth parts. There is a pair of minute rudimentary sense organs and a pair of prominent mouth hooks which work vertically to tear the tissues upon which the larva feeds or into which it tunnels. The larvæ typically have a complex pair of spiracles on the truncate last segment of the abdomen (Fig 561, *f*), and, sometimes at least, another pair near the front end of the body; but commonly none along the sides of the body on the other abdominal segments. Such larvæ are called *maggots*. They live mostly buried or hidden in decaying animal or vegetable matter, in water or mud, or inside the bodies of plants, insects, and other animals. There are strikingly few that feed externally upon plants and comparatively few crop pests of any kind. The most serious are certain gall flies like the Hessian fly (p. 359), the many fruit flies of the family Trypetidæ, some leaf miners,

FIG. 159.—A black fly, *Simulium* sp., female, side view enlarged. (*From Osborn, "Agricultural Entomology," after U. S. D. A.*)

FIG. 160.—A robber fly, side view, natural size. (*From Kellogg's "American Insects."*)

root maggots, and borers in the stems of plants. The attacks of the larvæ and adults upon animals are much more serious. This is the most dangerous order for the carrying of human and animal diseases (see pp. 22-25). Many species suck the blood of animals as adults or live as larvæ in their bodies. On the other hand, we must note the great benefit that accrues to us from the work of scavenger larvæ and from those that are predaceous or parasitic on various insects.

The pupæ of Diptera (Fig. 84, *G*, *H*) have the appendages free from the body wall and can be distinguished from the pupæ of all other orders by having a single pair of wing pads. In the higher families, the pupa is protected in a unique manner. Instead of shedding the skin of the last active larval instar, when the pupa is formed, this larval skin is retained about the pupa and serves like a cocoon. It is often inflated like a large seed and its walls become very hard and thickened to form an airtight and water-tight case. Such a case about a larva or pupa is called a *puparium* (Figs. 36, *D*, and 85, *C*). All flies of the suborder Cyclorrhapha spend the pupa stage in a puparium; most of the suborder Orthorrhapha do not.

In the latter group, the pupa commonly has no particular protective covering; rarely a cocoon is formed.

A good many of the flies are ovoviviparous, and in this order we have a few groups in which a viviparous reproduction occurs; for example, the Hippoboscidæ and the tsetse flies of the family Muscidæ. Another remarkable method of reproduction is the production of young by larvæ

FIG. 161.—A bee fly, *Bombylius major* Linné. Twice natural size. (*From Kellogg's "American Insects."*)

and pupæ, to which the term *pædogenesis* is applied. This occurs in certain of the gall midges.

It is easy to mistake many of the flies for other kinds of insects. If the student is not careful to watch the number of wings and especially for the presence of halteres, he will be likely to place many of his flies as Hymenoptera, because they are commonly banded with yellow and black,

FIG. 162.—A thick-headed fly, *Physocephala affinis* Williston, enlarged one-half. (*From Kellogg's "American Insects."*)

FIG. 163.—A trypetid fly, the white-banded cherry fruit fly, *Rhagoletis cingulata* Loew, female, enlarged. (*From Lochhead, "Economic Entomology," after Caesar*)

like the wasps, or hairy, like bees. A few species are louselike or ticklike in form, and these can be distinguished from ticks by the number of legs and from lice by the nature of the mouth parts, which are exposed, piercing organs.

Small- to medium-sized, thinly chitinized insects. Adults with only one pair of wings, the front pair, which are narrow, membranous, with few veins.

The hind wings are modified into halteres. Head, thorax and abdomen very distinct. Compound eyes and three ocelli usually present. Mouthparts sponging or piercing-sucking. Prothorax and metathorax fused with the mesothorax, but scutellum distinct. Metamorphosis complete. Larvæ legless, usually maggot-like with head greatly reduced; the mouthparts in these cases replaced by a pair of mouth hooks. Larval spiracles generally restricted to a small pair on prothorax and a large group on last segment of abdomen. Pupa with free appendages but often enclosed in a puparium.

There are comparatively few crop pests, but many that attack animals. The following are the most important and the student should refer to them for additional figures and descriptions: Hessian fly (p. 359), cabbage maggot (p. 505), onion maggot (p. 491), apple maggot (p. 584), clover seed midge (p. 405), mosquitoes (p. 827), black flies (p. 832), horseflies (p. 768), horse bots (p. 776), ox-warble flies (p. 791), screw-worm fly (p. 795), horn fly (p. 782), sheep "tick" (p. 803), and house fly (p. 855).

Specialists are fairly well agreed about the classification of the Diptera, at least in its major aspects.

A SYNOPSIS OF THE ORDER DIPTERA

A. Suborder *Orthorrhapha.*—Straight-seamed Flies.

The adult insects escape from the pupal skin or pupal case through a T-shaped or straight split down the back or a transverse split between the seventh and eighth segments of the abdomen. Pupa usually naked. Adults do not have a small, lunate-shaped sclerite above the antennæ known as the frontal lunule. Larvæ often with a distinct head.

1. *Nemocera. The Long-horned Flies.*—Antennæ usually long and slender, of 6 to 39 segments. Palps usually four- or five-segmented. Larvæ have a distinct head, eyes, and true mandibles working transversely. First anal cell of wings almost never narrowed toward the wing margin.

    Family 1. Crane flies, Family Tipulidæ (Fig. 157)
    Family 2. Moth flies and sand flies, Family Psychodidæ
    Family 3. Midges, Family Chironomidæ
    Family 4. Mosquitoes, Family Culicidæ
    Family 5. Gall gnats, Family Cecidomyiidæ (Itonididæ) (Fig. 158)
    Family 6. Fungus gnats, Family Mycetophilidæ
    Family 7. Buffalo gnats or black flies, Family Simuliidæ (Fig. 159)

2. *Brachycera. The Short-horned Flies.*—Antennæ usually short, of three segments, sometimes with a style in addition, like a small whip of withered segments at the end. Palps one- or two-segmented. Larvæ often have the head invaginated and mouth hooks working vertically, instead of mandibles. First anal cell always closed or narrowed toward the wing margin.

    Family 8. Horseflies, Family Tabanidæ
    Family 9. Soldier flies, Family Stratiomyiidæ
    Family 10. Robber flies, Family Asilidæ (Fig. 160)
    Family 11. Bee flies, Family Bombyliidæ (Fig. 161)
    Family 12. Long-legged flies, Family Dolichopodidæ

B. Suborder *Cyclorrhapha.*—Circular-seamed Flies.

The adults escape from the pupal case through a split that runs round the end of the case and releases a circular lid that is pushed off or aside. Pupa always

enclosed by the skin of the last active larval stage, which hardens to form a puparium. Adults with a frontal lunule and antennæ generally of three segments, the third bearing an arista or style. Head of larvæ always greatly reduced and invaginated into the pharynx. First anal cell always closed.

3. *Aschiza. Flies without a Frontal Suture.*—Cap of puparium pushed off by expansion of the face of the adult, when it is ready to emerge.

   Family 13. Flower flies or hover flies, Family Syrphidæ (see Fig. 36)

4. *Schizophora. Flies with a Frontal Suture.*—A line or seam circles round above the base of the antennæ and sometimes extends down nearly to the mouth on either side of the face. This is the vestige of a crack in the head through which a membranous, expansible, bladder-like structure, known as the *ptilinum*, is forced out when the adult is ready to emerge. By inflating the ptilinum with body fluids the cap of the puparium is forced off. The bladder is then withdrawn into the head and is seen only if one catches the adult very shortly after its emergence.

   (*a*) Acalyptratæ. Flies with small *tegulæ;* that is, small, flat membranous expansions connecting the base of the wing, behind, to the thorax. They do not have a complete transverse suture across near the middle of the thorax. They are all small flies, some very small. The eyes of males do not come together on top of the head.

   Family 14. Thick-headed flies, Family Conopidæ (Fig. 162)
   Family 15. Fruit flies, Family Trypetidæ (Fig. 163)
   Family 16. The frit fly and others, Family Oscinidæ
   Family 17. The pomace fly and others, Family Drosophilidæ

   (*b*) Calyptratæ. Flies with well-developed *tegulæ*, that is, thin, subcircular membranes just behind the base of the wing close against the thorax (see Fig. 156). The thorax has a complete transverse suture near midlength, above. This division includes our commonest and best-known flies. They are all medium to large in size. The males can be recognized by having the eyes contiguous, at least for a short distance, at the top of the head.

   Family 18. Anthomyid flies, Family Anthomyiidæ
   Family 19. House fly family, Family Muscidæ
   Family 20. Flesh flies, Family Sarcophagidæ
   Family 21. Tachina flies, Family Tachinidæ
   Family 22. Bot flies, Family Œstridæ (see Figs. 533 to 535)

5. *Pupipara.*—Louselike, often wingless flies, with a very tough skin, indistinctly segmented abdomen, and legs inserted far apart on the sternum. External parasites on mammals, including bats, on birds, or on insects. The larvæ developed viviparously until full grown and born shortly before pupation, all growth taking place at the expense of the mother fly which nourishes the larva from special uterine glands. Antennæ one- or two-segmented.

   Family 23. The sheep tick and louse flies, Family Hippoboscidæ (see Fig. 540)
   Family 24. Bee lice, Family Braulidæ

CHAPTER IX

INSECT CONTROL

To a large extent, the value of entomology is based on insect control. To a still greater extent the support given to this branch of science by the public is in direct proportion to the efficiency of measures for insect control which have been developed by entomological workers. While the lessening of insect damage or the control of insect outbreaks is not the end and aim of all insect study it is the most important. The study of insects is also of the greatest value in helping to solve some of the questions arising in the field of general biology, and in aiding in the understanding of the natural laws governing the development and abundance of plants and animals.

Insect control in its broadest sense includes everything that makes life hard for insects and tends to kill them and prevent their increase or spread over the world. The control of insects can be accomplished in many ways, which may be classified as follows:

AN OUTLINE OF CONTROL MEASURES FOR INSECTS

A. **Applied Control:**

Measures to destroy insects, that depend upon man for their application or success and can be influenced by him to a considerable degree.

I. Chemical Control:

(*a*) *Insecticides:* Substances that kill insects by their chemical action.

1. *Stomach Poisons:* sprays, dusts, or dips that kill the insect when they are swallowed.
   Examples: Arsenate of lead, calcium arsenate, Paris green, sodium fluoride, hellebore.
2. *Contact Poisons:* sprays, dusts, or dips that kill the insect without being swallowed.
   Examples: nicotine preparations, lime-sulfur, oil emulsions, pyrethum, derris.
3. *Fumigants:* chemicals used in the form of a gas to kill insects; usually applied in an enclosure of some kind.
   Examples: hydrocyanic acid gas, carbon bisulfide, nicotine, sulfur dioxide, paradichlorobenzene.

(*b*) *Repellents:* Substances that keep insects away from crops and animals, because of their offensiveness.
Examples: Bordeaux mixture, creosote, napthalene, oil of citronella.

II. Physical or Mechanical Control: Special operations against insects which kill them by their physical or mechanical action.

(*a*) *Hand Destruction:* hand-picking, jarring, swatting, worming.

(*b*) *Mechanical Exclusion:* screening, tree-banding, linear barriers, fly nets.

(c) *Use of Traps and Collecting or Crushing Machines.*
(d) *Artificial Cooling, Superheating, Burning.*
(e) *Flooding, Draining, Dehydration of Breeding Media.*
(f) *Use of Electricity.*

III. **Cultural Control or Use of Farm Practices:** Regular farm operations performed so as to destroy insects or prevent their injuries.
(a) *Crop Rotations.*
(b) *Tilling of the Soil.*
(c) *Variations in the Time or Method of Planting or Harvesting.*
(d) *Destruction of Crop Residues, Weeds, Volunteer Plants, Trash.*
(e) *Use of Resistant Varieties.*
(f) *Pruning, Thinning.*
(g) *Fertilizing and Stimulating Vigorous Growth.*

IV. **Biological Control:** the introduction, encouragement, and artificial increase of predaceous and parasitic insects, other animals, and diseases.
(a) *Protection and Encouragement of Insectivorous Wild Birds and other Animals.*
(b) *Use of Domesticated Fowls and Mammals.*
(c) *Introduction, Artificial Increase, and Collonization of Parasitic and Predaceous insects.*
(d) *The Spread and Increase of Fungous, Bacterial and Protozoal Diseases of Insects and the Liberation of Infected Insects.*

V. **Legal Control:** the control of insects by controlling human activities.
(a) *Inspection and Quarantine Laws to prevent the introduction of new pests from foreign countries or their spread within a country.*
(b) *Laws to Enforce the Application of Control Measures, such as spraying, the cleaning up of crop residues, fumigation, and eradication measures.*
(c) *Insecticide Laws to govern the manufacture and sale, and prevent the adulteration and misbranding of insecticides.*

B. **Natural Control:**
All of the measures that destroy or check insects which do not depend upon man for their continuance or success, and cannot be greatly influenced by man.

I. **Climatic Factors** such as rainfall, sunshine, cold, heat, and wind.
II. **Topographic Features,** such as rivers, lakes, mountains, type of soil, and other characteristics of the country that serve as barriers.
III. **Predators and Parasites** naturally present in the region, including insects, birds, reptiles, mammals.
IV. **Insect Diseases** naturally present in the region, such as entomophagous fungi and bacteria.

A. APPLIED CONTROL

Applied control includes those methods under the control of man, which it is necessary to use when harmful insects have not been held in check by natural factors. Under this heading we have (*a*) chemical control by the use of insecticides and repellents, (*b*) physical or mechanical control by specially designed machines or other devices, (*c*) cultural control by variations in the usual farm operations, (*d*) biological control by the introduction and establishment of insect enemies, and (*e*) legal control, by regulating commerce and other human activities that affect the prevalence and distribution of dangerously destructive insects.

Applied control of insects is, as a rule, expensive, and the amount which one can reasonably expect to save by the control applied must be weighed against the expense involved. When insects are present in numbers sufficient to cause a heavy loss of property, there is usually a strong desire on the part of the property owner to stop this loss. The cost of killing or checking the insects causing the trouble must be carefully considered, and the most economical means of efficient control employed.

A practical applied method of control has not been worked out for many of the insects attacking field and forest crops, and certain classes of those attacking live stock and man. Applied-control measures have been developed for most of the orchard, truck-crop, greenhouse, stored-grain, shade-tree, and household insects.

Insecticides

Insecticides are those substances which kill insects by their chemical action. Insecticides may be grouped into three general classes: (1) stomach poisons, (2) contact poisons, and (3) fumigants. Fumigants or poison gases are generally the most effective insecticides to use when the insects and the products they are damaging are in a tight enclosure like a house, storeroom or greenhouse. Sometimes fumigants are used to destroy insects in their burrows in the soil or in wood, and sometimes portable enclosures are placed over plants out-of-doors to fumigate them. Generally when plants, animals, or products in the open are to be treated, a spray or dust is applied. These are of two fundamentally different kinds known as *stomach poisons* and *contact poisons*.

If the insect to be destroyed has chewing mouth parts (see Figs. 61 and 62), or the plants are found to be riddled with visible holes (Fig. 1*B*), a stomach poison should be used. If the insect has piercing-sucking mouth parts (see Figs. 63 and 64), or the plants are wilted, yellowed, browned, or white-spotted or the leaves curled, but without visible holes (see Fig. 2), a contact poison should be used. Contact poisons may sometimes be used for chewing insects, but stomach poisons have not been successfully used to kill insects with piercing-sucking mouth parts.

Stomach Poisons

(See Tables VII and VIII)

Insecticides of this class are used to poison the food of insects. They are generally applied against chewing insects but may also be used for insects with sponging, siphoning, or lapping mouth parts under certain conditions. There are two principal ways of using stomach poisons: first, by the use of poison baits—mixing the poison with a substance that is more attractive or tasty to the insect than its usual food; secondly, by

covering the plants so thoroughly with the poison that the insect will get a fatal dose in taking its usual food.

A satisfactory stomach poison must be sufficiently active to kill quickly. It must be inexpensive. It must be a sufficiently stable chemical compound so that it can be mixed with other chemicals in water, or as a dust, without changing its toxicity or making it harmful to plants. It must remain stable during shipment and storage. It must be generally available in large quantities. It must not repel the insects against which it is to be used. It must spread uniformly and adhere well to the plant surfaces to which it is applied. If applied to plants it must not burn the foliage. The ideal insecticide should not leave any residue dangerous to the health of man or animals on the plants treated.

The margin of safety between a dose of poison necessary to kill the insect and the slightly larger dose that will burn or damage the plant, is very slight, and few substances meet all of the above requirements. The most widely used stomach poisons are those composed of some form of arsenic, such as Paris green, arsenate of lead, calcium arsenate, zinc arsenite, and many others. Some stomach poisons are also made from plants which contain substances like hellebore that are poisonous to insects. Many other chemicals besides arsenic have been found toxic to insects, but only a few of them, like sodium fluoride, have come into general use as insecticides.

The Arsenicals.—The arsenicals, particularly arsenate of lead and arsenate of lime, have, except for the residues which they leave, met nearly all of the requirements for a satisfactory stomach poison. For this reason, no great effort was made for many years to develop others. The demand for arsenic has become so great at times in the past that the material has increased in price and the amount available has been hardly sufficient to meet the needs. More than 31,000,000 pounds of calcium arsenate, 11,000,000 pounds of arsenate of lead, and 3,000,000 pounds of Paris green were used in the United States in 1923. Most of the arsenic is now obtained as a by-product in mining and smelting other metals, mainly copper and silver. There are large deposits of ores high in arsenic content in several countries of the world, and these will possibly be worked for the arsenic alone if the present demand for this poison continues. There is also a probability that other poisons will be utilized to a much greater extent. Several oil and coal-tar products and the salts of other metals offer promise in this field.

Generally speaking, the killing power of an arsenical is in direct ratio to the percentage of metallic arsenic it contains. The danger of "burning" or injury to plants is in direct ratio to the percentage of its arsenic that is present *in water-soluble form;* since such water-soluble arsenic can enter the living parts of the plant foliage and poison them. The ideal arsenical would be one having a very high arsenical content, none of which

should be soluble in water but all of it readily soluble in the digestive juices of the insect.

Arsenate of Lead.—Of the stomach poisons, the best known and most widely used is arsenate of lead. There are two forms of arsenate of lead, the basic or triplumbic lead arsenate, $Pb_4(PbOH)(AsO_4)_3.H_2O$ and the acid or hydrogen, diplumbic lead arsenate, $PbHAsO_4$.[1] The latter form is the one most generally used. It is somewhat more likely to burn tender plants than the basic form, but its quicker killing power makes it the more desirable. It is the form used in nearly all commercial lead arsenates. It is light and fluffy, and for this reason, stays in suspension well. Once dried on the foliage, it adheres for a long time. It contains a high percentage of arsenic (equivalent to about 33 per cent As_2O_5), and is sufficiently stable so that it can be used with many other compounds without breaking down.

The basic lead arsenate is of a heavy granular nature and does not stay in suspension well. It contains a lower per cent of arsenic than the acid (about 23 per cent As_2O_5), which partly accounts for its slower kill. It is a more stable compound and for this reason will not burn tender foliage. This also reduces its killing power, as it is not so easily acted on by the digestive fluids of insects, and for this reason tends to pass through the body and be discharged in the excreta. While it will kill most chewing insects, it requires a longer time and a larger amount than the acid lead arsenate. The basic lead arsenate is not generally sold on the market, but can be obtained from any of the large dealers in insecticides, if needed for very susceptible plants or for use in regions of very high humidity where the acid arsenate sometimes breaks down and causes burning.

Lead arsenate was first used as an insecticide in Massachusetts, in 1892, and was developed by the federal Bureau of Entomology, in connection with their work of controlling the gypsy moth, in response to the need of a stomach poison that could be applied at greater strength than Paris green without burning. The chief reason why arsenate of lead does not usually burn the foliage is because nearly all of the arsenic is insoluble. The federal insecticide law forbids the sale of arsenate of lead with more than three-fourths of 1 per cent of the arsenic in water-soluble form. Arsenate of lead has been on the market as a paste and a powder. The paste contains about 50 per cent water, when fresh, and should be used at twice the amount, by weight, of the powdered form. It is now sold almost entirely in the form of a light dry powder. Arsenate of lead (acid

[1] According to the California Department of Agriculture: "Acid or standard arsenate of lead is a chemical combination of arsenic pentoxide and lead monoxide containing *not less than* 30 *per cent arsenic pentoxide* and *not less than one part of arsenic pentoxide to* 2.14 *parts of lead monoxide.* Basic arsenate of lead is a chemical combination of arsenic pentoxide and lead monoxide containing *not less than* 22 *per cent of arsenic pentoxide and not more than one part of arsenic pentoxide to* 3.10 *parts of lead monoxide.*"

TABLE VII.—POISONS TO BE USED FOR CHEWING INSECTS

The best poison to use for chewing insects is one that kills quickly, sticks well to the foliage, without burning, does not readily settle in the sprayer, and can be purchased at a moderate price.

The insecticides in most general use for controlling chewing insects are the following:

Stomach poison	Time of killing	Adherence to foliage	Injury to plants	Quality of suspension	Price	How applied	Best uses
Arsenate of lead	Quickly	Very well	Very slight tendency to burn	Settles moderately	Moderate; 15¢ to 60¢ a pound	Dust, spray, and in combinations	Best spray for most chewing insects
Calcium arsenate	Rather slowly	Well	Tendency to burn	Settles moderately	Moderate; 10¢ to 50¢ a pound	Dust, spray, and in combinations	Fairly good for most chewing insects
Paris green	Very quickly	Poorly	Burns tender foliage	Settles rapidly	Moderate; 25¢ to $1 a pound	Dust, spray, and in combinations	For potato and other hardy plants
Zinc arsenite	Very quickly	Very poorly	Burns all but hardiest foliage	Settles rapidly	Cheap; 20¢ to 75¢ a pound	Dust, spray, and in combinations	Used only on potatoes and hardiest plants
Magnesium arsenate	Quickly	Well	Slight tendency to burn	Settles very slowly	Moderate; 20¢ to 75¢ a pound	Dust, spray, and in combinations	Effective for most chewing insects
Crude arsenious oxide	Rather slowly	Moderately well	Burns severely	Settles moderately	Cheap; 10¢ to 40¢ a pound	Poison baits only	For grasshoppers, cutworms and army worms
Sodium arsenite	Rather quickly	Poorly	Burns severely	Soluble in water	Cheap; 10¢ to 40¢ a pound	Spray and poison baits	For grasshoppers, cutworms and army worms
White arsenic	Very quickly	Moderately well	Burns severely	Settles very little	Cheap; 12¢ to 50¢ a pound	Poison baits	For grasshoppers, cutworms and army worms
London purple	Quickly	Poorly	Burns all but hardiest foliage	Settles rapidly	Cheap; 25¢ to $1 a pound	Dust and spray	Variable in quality, not recommended
Sodium fluoride	Slowly	Very poorly	Burns severely	Soluble in water	Moderate; 30¢ to 75¢ a pound	Dip or dust on animals or in houses	For household insects and chewing lice
Fluosilicates	Slowly	Very poorly	Slight to severe burning	Settle slowly	Cheap; 12¢ to 50¢ a pound	Dust and spray	For beans, cotton and other crops
Hellebore	Slowly	Very poorly	Does not burn	Settles slowly	High; 20¢ to $1 a pound	Dust and spray	On tender plants and wherever arsenicals would endanger human health

Table VIII.—Poisons to Be Used for Chewing Insects

Amount of Poison Required for Following Amounts of Spray

Kind of spray	200 gallons	150 gallons	100 gallons	50 gallons	25 gallons	5 gallons	1 gallon
Arsenate of lead, in powder form	4 pounds	3 pounds	2 pounds	1 pound	8 ounces	1.6 ounces	1/3 ounce or 3 teas
Arsenate of lead, in paste form	8 pounds	6 pounds	4 pounds	2 pounds	1 pound	3.2 ounces	2/3 ounce or 1 tea.
Calcium arsenate in powdered form	3 pounds	2.25 pounds	1.5 pounds	12 ounces	6 ounces	1.2 ounces	1/4 ounce or 2 teas.
Paris green	2 pounds	1.5 pounds	1 pound	1/2 pound	4 ounces	0.8 ounce	1/6 ounce or 1.5 teas.
Zinc arsenite	4 pounds	3 pounds	2 pounds	1 pound	8 ounces	1.6 ounces	1/3 ounce or 3 teas.
Magnesium arsenate	4 pounds	3 pounds	2 pounds	1 pound	8 ounces	1.6 ounces	1/3 ounce or 3 teas.
Sodium arsenite	4 pounds	3 pounds	2 pounds	1 pound	8 ounces	1.6 ounces	1/3 ounce or 3 teas.
Hellebore	Use for garden spraying only				3 pounds	10 ounces	2 ounces

or basic) may be safely combined with nicotine, lubricating-oil emulsion, Bordeaux mixture, lime-sulfur, self-boiled lime and sulfur, and "dry-mix." It should not be used with sodium and potassium sulphide or ordinary soaps. The dosage varies greatly for different insects. An average strength is about ⅓ ounce to each gallon of water or other spray, or 1 pound to the barrel.

Arsenate of Lime or Calcium Arsenate ($Ca_3(AsO_4)_2$).—Early experiments with this material showed that it is likely to burn the foliage of all but the most hardy plants. About 1915, experiments conducted by the federal Bureau of Entomology demonstrated that this arsenical, when manufactured in the proper form, is nearly as safe as arsenate of lead. It is a somewhat more unstable compound than arsenate of lead, and only fresh material should be used. This arsenical should never be used on the stone fruits. It is in general more fluffy and bulky than arsenate of lead, and for this reason is better adapted for use in dusting plants. Arsenate of lime may be obtained in both paste and powder form, but the latter is by far the most desirable for general use. Arsenate of lime has a higher killing power than an equal weight of arsenate of lead, as it contains arsenic equivalent to from 42 to 48 per cent As_2O_5. With tender foliage, at least equal amounts by weight of fresh lime or one and one-half by weight of hydrated lime should be added to prevent burning of foliage. Calcium arsenate may be safely combined with nicotine, lime-sulfur, or Bordeaux mixture. It should not be used with soaps. An average strength is ¼ ounce to each gallon of water, or ¾ pound to the barrel.

Paris Green ($3CuOAs_2O_3 \cdot Cu(C_2H_3O_2)_2$).—This form of arsenical was the first stomach poison to come into general use for spraying plants. Its use originated in the west central United States about 1865, against the Colorado potato beetle. It remained the leading stomach poison until the discovery of arsenate of lead in 1893. It is one of the quickest-killing insecticides, but is likely to burn foliage. The chemical name of Paris green is aceto-arsenite of copper. It usually contains arsenic equivalent to more than 50 per cent As_2O_5, from 2 to 3 per cent of which is generally in water-soluble form. It also contains about 30 per cent copper oxide and 10 per cent acetic acid, which are of little value in the spray. It does not stick well, and it settles rapidly. Arsenate of lead and arsenate of lime have largely taken its place. It may be used in combination with Bordeaux mixture, but not with lime-sulfur, soaps, or sulfides. It should never be used on any of the stone fruits. It is fairly efficient in poison baits and is sometimes used in sprays or dusts for insects which are very hard to kill. An average strength is ½ pound of Paris green and 1 pound of lime to 50 gallons of water.

White Arsenic, or Arsenic Trioxide, or Arsenious Oxide (As_2O_3).—This is a very active poison and is one of the cheapest arsenicals. It is the form from which all other arsenicals are derived. Because it is com-

pletely soluble in water, it is so likely to burn foliage that it is not safe to use in spraying plants, but it is used in poison baits. It is sold in the form of a white powder. When dissolved in water, it forms arsenious acids. These acids acting upon bases produce the series of salts known as *arsenites;* for example, Paris green and arsenite of soda.

Arsenic Pentoxide or Arsenic Oxide (As_2O_5).—Arsenic forms another oxide known as arsenic pentoxide. With water, arsenic pentoxide forms arsenic acids and the action of these acids on bases produces the series of salts known as *arsenates*. The arsenates are, in general, less toxic than the arsenites, but because of greater stability are less likely to burn plants and consequently are of greater value as insecticides.

Arsenate of Soda ($Na_3AsO_4.12H_2O$).—This is a highly soluble form of arsenical which cannot be used for spraying the foliage of plants. It is used in poison baits and for making other, more stable, insecticides.

Arsenite of Soda ($Na_2As_2O_3$).—This is a very highly soluble form of arsenical used mainly in poison baits and stock dips, and generally sold in liquid form. It is extremely toxic to plants and is extensively used as a weed killer.

Arsenite of Zinc ($Zn(AsO_2)_2$).—This arsenical has been used to some extent for spraying potatoes and some other plants with hardy foliage. It is likely to cause severe burning, and should not be used for spraying any of the orchard or bush fruits.

Magnesium Arsenate ($Mg_3(AsO_4)_2$).—This arsenical has been used extensively for combating the Mexican bean beetle, because it does not burn the foliage of beans. It is less toxic than arsenate of lead or arsenate of lime.

There are several other arsenical compounds that have been used to a limited extent, but which have not proved of sufficient value to warrant their general adoption, mainly because of their liability to burn foliage. Among these may be mentioned arsenite of lime, arsenite of lead and London purple.

Non-arsenical Stomach Poisons.—The most important of the stomach poisons that do not contain arsenic are sodium fluoride, the fluosilicates and hellebore.

Sodium Fluoride[1] (NaF).—This poison has come into general use during the past ten years as a means of combating chewing lice on animals and poultry, and for the control of household pests, particularly cockroaches. While it is primarily a stomach poison, it also acts to a slight extent as a contact poison when the powder or solution is taken into the tracheæ. The commercial form of sodium fluoride is used undiluted as a powder or mixed with other, non-toxic, dusts and in solution. It should not be sprayed on the foliage of plants. Sodium fluoride is poisonous to

[1] This should not be confused with *sodium chloride*, common salt, as the names sound much alike.

man and should not be sprinkled over foods. It is also somewhat irritating to the skin and to the respiratory passages.

Fluosilicates.—Recent work has shown that the fluosilicates of sodium, calcium and several other bases, and also cryolite, offer considerable promise as stomach poisons. The work with these materials is still in the experimental stage.

Hellebore.—Of the many plant products that have been tried as poisons for chewing insects, hellebore is by far the best known. This form of insecticide is made from the dried and powdered roots of hellebore plants. The white hellebore (*Veratrum album*) was formerly the only variety used, but the American hellebore (*Veratrum viridis*) has been found to be as effective. It is quite toxic to insects when fresh, but very mildly so to the higher animals. Hellebore is expensive, but, because its poisonous principle is volatile, it may be used to advantage on nearly ripe fruits and mature leafy vegetables, which should not be treated with arsenicals because of danger to the consumer. It must be stored in a tightly closed receptacle. It may be combined with any fungicide, or with contact insecticides. It is used as a dust diluted with flour or lime or as a tea at the rate of 1 or 2 ounces to the gallon of hot water.

There are many other substances that have possibilities as stomach poisons for chewing insects, but those given are the ones in general use at present.

Poison Baits.—In certain cases where spraying is not practicable, as for certain household insects, fruit insects, insects that work underground, and chewing insects attacking areas of crops too great to be protected by spraying, stomach poisons may be mixed with materials known to be attractive to the particular pest, and such *poisoned bait* exposed where the insects may get it.

Poison Baits for Grasshoppers, Cutworms, Army Worms, Crickets, and Earwigs.—For these insects a very strong and soluble form of arsenical is generally used. Arsenate of lead should never be used, since it is too weak a poison; white arsenic, Paris green, and arsenite of soda are commonly used. Sodium fluoride has been recommended as a poison in baits for the European earwig and grasshoppers. The most common carrier is wheat bran, moistened with enough water to make it thoroughly wet but not enough to drip without being squeezed. Sometimes middlings, alfalfa meal, hardwood sawdust, fresh horse droppings, or even squares of newspaper are used as the carrier. "Black strap" molasses is usually added, and frequently other attrahents, such as chopped whole oranges or lemons, amyl acetate, salt, watermelon, and apple are recommended. A tried and tested formula is:

Wheat bran	25 pounds
White arsenic, Paris green, or sodium arsenite	1 pound
Blackstrap molasses	2 quarts
Water, enough to make a stiff mash, usually	3 gallons

The bran and poison are very thoroughly mixed while dry. A part of the water is added to the molasses, and the bran and poison moistened with it by shoveling over and over, more water being added until the desired wetness of the mash is secured.

Such poison baits are usually scattered thinly over the ground in infested fields, 5 to 10 pounds being required to cover an acre. For grasshoppers, the bait should be distributed in the morning so as to be fresh when the hoppers begin feeding. For cutworms, army worms and earwigs, the bait is best distributed in the evening, since these insects are nocturnal.

Poison Baits for Ants.—These have been extensively used for the Argentine ant and to a less extent for other species. For the former species at least, it has been found desirable to use syrup very weakly poisoned with chemically pure arsenite of soda, in order that the worker ants, which alone forage in houses and orchards, may have time after eating the poison bait to carry it back to the nest and feed some of it to the queens and the larvæ. In this way the entire colony can be killed. Several formulæ found effective for ants are given on page 737. These syrups are put in tin boxes or cans having a piece of sponge in the bottom and the covers having holes punched in them or fitting on so as to leave passages through which the ants can enter the boxes. These boxes are placed along the runways of the ants out of the reach of children and kept filled so that a part of the sponge is above the syrup. From 75 to 150 such cans are used in each city block when fighting the Argentine ant, and entire municipalities have been freed of this pest by this method. Fall and early spring are the best times to use this control.

Poison Baits for Flies and Moths.—Commercial poisoned fly papers to be soaked in sweetened water have been used for years against the house fly. A mixture of 1 tablespoonful of formalin in 1 pint of mixed water and milk is also commonly recommended for this pest. Bishopp recommends poisoning the screw-worm fly by the use of carcasses of large or small animals, partially skinned, the flesh slashed, and a solution of 1 pound white arsenic dissolved by boiling in 5 gallons of water poured freely over the flesh. The fruit and vegetable flies, whose maggots develop internally in a great variety of fruits and vegetables, have been killed in many parts of the world with mixtures of sodium arsenite, potassium arsenate, lead arsenate, or other arsenical, in molasses and water. These mixtures are frequently sprayed over the foliage of the plants on which the maggots are feeding, and the adult flies lap up the tiny droplets of sweetened poison from the leaves. Poisoned baits consisting of molasses or saccharine in water have also been tried for moths whose larvæ are destructive to crops. Recently extensive attempts to bait the Oriental fruit moth have been carried on in which a great variety of attrahents, such as amyl acetate, allyl alcohol and ethyl alcohol have

been tried, but so far without leading to practical recommendations for control.

Contact Poisons

(See Tables IX and X)

In order to kill an insect with stomach poisons the insect must swallow the poison. Insects with piercing mouth parts take their food from beneath the surface and consequently get none of the poisons applied to the surface of foliage or fruits; and no effective method of poisoning the sap of plants has ever been discovered. Consequently for the piercing-sucking plant pests we must use a contact poison.

Insecticides of this class are used in liquid and dust form to kill insects by coming in contact with or entering their bodies, *other than by the mouth*, and especially through the spiracles. There are many kinds, of which the following are the more important: (*a*) organic substances such as nicotine, pyrethrum, derris, quassia, and other alkaloids; (*b*) caustic inorganic compounds like lime-sulfur; (*c*) oils; (*d*) soaps; and (*e*) sulfur and other dusts. They kill insects by entering the tracheæ as liquids or gases, and producing a chemical action on the body contents, or, rarely, by their physical action in clogging the breathing tubes and smothering the insects.

Contact poisons are used chiefly for piercing-sucking insects (Fig. 63) that suck the juices of plants or the blood of animals. They are also used for certain kinds of chewing insects that cannot be readily killed by applying stomach poisons to their food.

In spraying or dusting with contact poisons, the aim should be to hit every insect present with the poison, since only those which are hit by it will be killed. Unlike stomach poisons, contact poisons cannot be applied in advance of an expected outbreak as a preventative.

In this class of insecticides, we have a greater variety and diversity of substances in general use than is the case with the stomach poisons. Many substances that act as contact insecticides are also toxic to plants, and the margin between the point of injury to the insect and injury to the plant is often small. For this reason, one must use caution in applying these insecticides. There are several plant products in general use in this class of insecticides which are quite effective against certain insects and which are very slightly toxic to plants.

Nicotine ($C_{10}H_{14}N_2$).—Of all contact insecticides, nicotine is probably the most widely used. Pure nicotine is a yellowish, oily liquid. It is extracted from tobacco as a solution, and is on the market in the forms of *nicotine sulfate* and of *free nicotine*. The manufactured nicotine solutions are sold under a number of trade names and at several strengths. The best-known brands in America contain 40 per cent by weight of nicotine.

Free nicotine is more active than the nicotine sulfate, and kills more quickly at a given strength, but its action does not extend over so long a period and for this reason it is not so effective in some cases. It is much more volatile than the nicotine sulfate, but both should be stored in tightly sealed containers. To be effective against most insects, the diluted spray should contain from 0.06 to 0.05 per cent of nicotine, or at a rate of 1 gallon of 40 per cent nicotine sulfate or free nicotine to 800 to 1,000 gallons of water. For small quantities, use 1 to 2 teaspoonfuls to each gallon of water. Unless an arsenical is to be used in the same mixture, soap should always be dissolved in hot water and added to the nicotine spray to aid in liberating the nicotine and serve as a spreader. A cubic inch of soap to each gallon of spray, or 2 or 3 pounds to the barrel, is the right amount. Soap-oil emulsions are also excellent spreaders and carriers for nicotine.

Owing to the cost of manufacture, nicotine is expensive. Nicotine extract may be made at home, but is hard to standardize because of the great variation in the nicotine content of tobacco even of the same variety when grown on different soils or under different weather conditions, or from different parts of the same plant. To make 100 gallons of a 0.05 per cent solution, according to the Virginia Agricultural Experiment Station, requires from 11¾ to 145 pounds of tobacco, depending on the amount of nicotine in the tobacco used.

Nicotine is also extensively used in dust form. In the dusts the nicotine is mixed with some diluent, as hydrated lime, sulfur, or other light, finely divided material. Both the forms of nicotine are employed in making dusts. The free nicotine is the more desirable in a hot, dry climate and the nicotine sulfate where the air is more humid. These dusts are not effective if applied when the plants to be treated are wet with dew or rain. A simple method of home-mixing nicotine dusts is here given. The advantages of home-mixing nicotine dusts are: a saving of nearly one-half of the cost of the prepared dust; fresh material which is of a higher killing power; and availability when needed without waiting for shipment from a distance. The kind of material used as a carrier in nicotine dusts has an important effect on the speed with which the nicotine is released as a gas.

For mixing small quantities of dust, place the hydrated lime, dusting sulfur, or other dust to be used as a diluent, in a can, churn, or small keg, which has a tight-fitting lid. Pour the correct amount of 40 per cent nicotine sulfate, or 40 per cent free nicotine, over the dust in the container; add 10 to 15 small stones about the size of hens' eggs, close the lid tightly and roll the container back and forth for 10 minutes. Do not roll rapidly, as the dust will mix better if the container is rotated at about 30 to 40 revolutions per minute. Be sure that the dust and nicotine are thoroughly mixed. If it is to be stored, it should be placed in a tight container, and kept in a dry, cool place. For a 1 per cent dust use 1¼ pounds 40 per cent free nicotine (or nicotine sulfate) to 48¾ pounds of the carrier.

Table IX.—Poisons to Be Used for Soft-bodied and Sucking Insects

Contact poisons are used for killing soft-bodied and piercing-sucking insects. They are effective only when applied directly to the body of the insect. The best poisons of this class are those that kill quickly, without injuring the plants, and that can be purchased at a moderate price.

Contact poison	Time of killing	Injury to plants	Price	How applied	Best uses
Nicotine sulfate	Quickly	Does not burn	Moderate; \$1.50 to \$2.50 a pound	Dust, spray, and in combinations	Best general insecticide for all soft-bodied sucking insects
Laundry soaps	Moderate to slowly	Slight to severe	Cheap; 8¢ to 10¢ a pound	Spray	Some soft-bodied insects
Fish-oil soaps	Quickly	Burn tender foliage	Moderate; 5¢ to 15¢ a pound	Spray	Certain sucking insects, as squash bug, harlequin cabbage bug
Kerosene emulsion	Quickly	Likely to burn foliage	Cheap; 20¢ to 50¢ a gallon	Spray	Sucking insects on plants with hardy foliage
Lubricating-oil emulsions	Moderately to slowly	None in dormant stage	Cheap; 20¢ to \$1 a gallon	Dormant spray or delayed dormant	Scale insects, mites, aphids
White-oil emulsions	Moderately	None on most trees	High; 60¢ to \$2 a gallon	Summer spray	Combined with nicotine sulfate for aphids, codling moth
Miscible oils	Quickly	None in dormant stage. Very likely to burn foliage	Moderate; 40¢ to \$1.50 a gallon	Dormant spray or delayed dormant	Scale insects and a few other sucking insects and mites
Liquid lime-sulfur	Slowly	None in dormant stage. Burns foliage[1]	Moderate; 12¢ to 75¢ a gallon	Dormant spray or delayed dormant; summer fungicide	Scale insects and mites
Dry lime-sulfur	Slowly	None in dormant stage. Burns foliage[1]	Moderate; 10¢ to 50¢ a pound	Dormant spray or delayed dormant	Scale insects and mites
Sodium sulfide	Slowly	None in dormant stage. Burns foliage	Moderate; 10¢ to 50¢ a pound	Spray on dormant trees	Scale insects and mites
Barium sulfide	Slowly	None in dormant stage. Burns foliage	Moderate; 10¢ to 50¢ a pound	Spray on dormant trees	Scale insects and mites
Tobacco dust (powdered tobacco plant)	Moderately	Does not burn	Moderate; 6¢ to 20¢ a pound	Dust on plants or soil	Kills soft-bodied insects and repels some others
Derris	Quickly	Does not burn	Moderate; \$1.50 to \$2.50 a pound	Spray	General insecticide for soft-bodied and sucking insects
Pyrethrum	Quickly	Does not burn	High; 75¢ to \$2.50 a pound	Spray and dust	For household insects and animal parasites

[1] Does not burn apple foliage if applied at summer strength.

TABLE X.—POISONS TO BE USED FOR SOFT-BODIED AND SUCKING INSECTS

Amount of Poison Required for the Following Amounts of Spray

Kind of spray	200 gallons	150 gallons	100 gallons	50 gallons	25 gallons	5 gallons	1 gallon
40 per cent nicotine sulfate (1 part to 800 parts water)	1 quart	1.5 pints	1 pint	8 fluid ounces	4 fluid ounces	0.8 fluid ounce	1 teaspoon
40 per cent nicotine sulfate (1 part to 600 parts water)	1.33 quarts	1 quarts	1.33 pints	10.66 fluid ounces	5.33 fluid ounces	1 fluid ounce	1.5 teaspoon
Lubricating-oil emulsion[1] (2 per cent oil)	6 gallons	4.5 gallons	3 gallons	1.5 gallons	3 quarts	0.6 quart	4 fluid ounces
Miscible oils	Use according to directions given by the manufacturers						
Kerosene emulsion[1] (10 per cent oil)	30 gallons	22.5 gallons	15 gallons	7.5 gallons	3.75 gallons	3 quarts	1.2 pints
Kerosene emulsion[1] (5 per cent oil)	15 gallons	11.25 gallons	7.5 gallons	3.75 gallons	1.87 gallons	1.5 quarts	0.6 pint
Laundry soaps	36.8 pounds	27.6 pounds	18.4 pounds	9.2 pounds	4.6 pounds	15 ounces	3 ounces
Fish-oil soaps	50 pounds	37.5 pounds	25 pounds	12.5 pounds	6.25 pounds	1.25 pounds	4 ounces
Lime-sulfur solution[2,3] (winter strength)	25 gallons	18.75 gallons	12.5 gallons	6.25 gallons	3.12 gallons	2.5 quarts	1 pint
Lime-sulphur solution[2,3] (summer strength)	4 gallons	3 gallons	2 gallons	1 gallon	2 quarts	0.4 quart	3 fluid ounces
Sodium sulfide (winter strength)	50 pounds	37.5 pounds	25 pounds	12.5 pounds	6.25 pounds	1.25 pounds	4 ounces
Barium sulfide (winter strength)	60 pounds	45 pounds	30 pounds	15 pounds	7.5 pounds	1.5 pounds	5 ounces
Dry lime-sulfur	Use according to directions given by the manufacturers						
Self-boiled lime and sulfur[3] (8-8-50 mixture):							
Stone lime	32 pounds	24 pounds	16 pounds	8 pounds	4 pounds	12 ounces	2.5 ounces
Sulfur	32 pounds	24 pounds	16 pounds	8 pounds	4 pounds	12 ounces	2.5 ounces
Bordeaux mixture[3] (3-5-50 mixture):							
Copper sulfate	12 pounds	9 pounds	6 pounds	3 pounds	1.5 pounds	5 ounces	1 ounce
Hydrated lime	20 pounds	15 pounds	10 pounds	5 pounds	2.5 pounds	8 ounces	2 ounces

[1] From $66\frac{2}{3}$ per cent oil in the stock emulsion.
[2] From 33° Bé. material.
[3] These sprays are important fungicides, useful for the control of plant diseases.

For a 2 per cent dust use $2\frac{1}{2}$ pounds 40 per cent free nicotine (or nicotine sulfate) to $47\frac{1}{2}$ pounds of the carrier.

For a 3 per cent dust use $3\frac{3}{4}$ pounds 40 per cent free nicotine (or nicotine sulfate) to $46\frac{1}{4}$ pounds of the carrier.

For a 5 per cent dust use $6\frac{1}{4}$ pounds 40 per cent free nicotine (or nicotine sulfate) to $43\frac{3}{4}$ pounds of the carrier.

The mixer should never be more than one-third full while it is being used. As the materials for making the dust will keep much better than the prepared dust, it is not advisable to make it in large quantities.

Nicotine is also used extensively for greenhouse fumigation and for stock dips to rid animals of parasites. Nicotine may be combined with most standard sprays, and, unless used at greater than the above strengths, will not injure the foliage of any but the most tender plants. For fumigating, the free nicotine should be used, since the nicotine sulphate is not readily volatile.

Pyrethrum Powders and Extracts.—The active killing agent of this insecticide is a volatile oil which is highly poisonous to most insects, but only mildly so to the higher animals. It is made from the dried heads of plants of three species[1] of the genus Chrysanthemum (Pyrethrum). As the oil is highly volatile, the insect-killing power of this material is soon lost if it is not kept in tight containers, and only fresh material should be used. The oil is driven off more rapidly at high temperatures, making this insecticide more effective under such conditions. It is too expensive for use on a large scale, but is of value for some insects in greenhouses, dwellings, and on outdoor flowering plants. The powdered flower heads are extensively used in fly poisons, bug poisons, and other commercial preparations sold under many trade names, such as Buhach, Persian, and Dalmatian insect powders. The active oil is also extracted from the flower heads and is used very extensively for fly sprays on animals and as household sprays for combating bedbugs, flies, and ants. It is the killing agent in most of these sprays. The use of pyrethrum originated in the Transcaucasus region of Asia, where for many years its nature was kept secret. It is now extensively grown and manufactured in California. Over 1,500,000 pounds of "insect powder" have been imported into the United States in a single year. The dry powder is dusted about dwellings or on infested plants; or a tea may be made by steeping 1 ounce of pyrethrum in 1 gallon of hot water. The field of usefulness for this insecticide has greatly increased during the past few years. More than 2,000 different preparations depending on this material for their killing agent are now on the market (Abbott).

Sulfur, Lime-sulfur and Other Sulfur Compounds.—Sulfur and its compounds are among the most important contact poisons. The following list will indicate some of its important uses:

[1] *Chrysanthemum cinerariæfolium*, *C. roseum*, and *C. marshallii*.

A. Sulfur Dusts:

(1) Especially toxic to mites, such as chiggers and red spider.

(2) Important as a fungicide carrier for other dust insecticides, such as nicotine and arsenate of lead. The following mixture or some modification of it is extensively used on peach.

Dusting sulfur	80 pounds
Hydrated lime	10 pounds
Arsenate of lead	10 pounds

B. Mechanical Spray Mixtures of Sulfur with other Substances:

(1) Sulfur-soap Spray for Mites:

Sulfur	10 pounds
Soap	2 pounds
Water	50 gallons

(2) New Jersey Dry-mix (a fungicide):

Superfine dusting sulfur	8 pounds
Hydrated lime ("finishing lime")	4 pounds
Calcium caseinate (a bi-product from creameries)	8 ounces

Use 12½ pounds of the mixture to 50 gallons of spray as a summer fungicide for apple and peach.

(3) Self-boiled Lime and Sulfur:

Sulfur	8 pounds
Unslaked lime (high-grade quick lime)	8 pounds
Water	50 gallons

The sulfur is intimately mixed with the lime by adding it as the lime begins to slake. The mixture is cooled before a chemical combination of the lime and sulfur takes place. Used as a summer fungicide for stone fruits and may aid in checking San José scale.

(4) Colloidal Sulfur:

Made by passing sulfur fumes into soap and water or glue and water, or by passing hydrogen sulfide (H_2S) gas into a solution of sulfur dioxide (SO_2). Recommended, in combination with arsenate of lead, for apple scab, codling moth and leaf rollers.

C. Chemical Compounds of Sulfur with Calcium, Sodium, Potassium, and Barium:

(1) Liquid, Fire-boiled Lime-sulfurs:

(*a*) Home-made concentrated lime-sulfur:

Unslaked lime (high-grade quick lime)	50 pounds
Sulfur (flowers or ground sulfur)	100 pounds
Water, enough to make	50 gallons

Boil together 45 minutes to 1 hour. Dilute with water to a strength of 5° Bé. before applying as a winter scalecide.

(*b*) Commercial Lime-sulfur:

Dilute to a strength of 5° Bé. before applying as a winter scalecide (1 part to 7 or 8 of water).

(2) Dry Sulfur Compounds:

(*a*) Dry lime-sulfur.

Use 15 or more pounds to 50 gallons of water as a winter scalecide.

(*b*) Sodium Sulfide Compound ("Soluble Sulfur Compound").

Use 12½ or more pounds to 50 gallons of water as a winter scalecide.

(*c*) Barium Tetrasulfide.

Use 15 or more pounds to 50 gallons of water as a winter scalecide.

(3) Potassium Sulfide:

Dissolved 1 ounce in 2 gallons of water forms an effective spray for red spider.

Sulfur and lime are both practically insoluble in water but when boiled together they combine to form a series of salts, some of which are soluble and others insoluble. Lime-sulfur is a mixture of the following compounds:

CaS_5—Calcium pentasulfide
CaS_4—Calcium tetrasulfide
CaS_2O_3—Calcium thiosulfate
$CaSO_3$—Calcium sulfite

The first three are soluble in water, the calcium sulfite is comparatively insoluble; and it, together with any uncombined sulfur or excess lime or magnesium or iron from impure lime, settles out and forms the sediment or "sludge" in home-boiled lime-sulfurs. In the commercial lime-sulfurs the sludge is removed before shipping. Of the first three compounds the pentasulfide and tetrasulfide, together called polysulfides, are believed to be the valuable ingredients, and it is to them that the lime-sulfur owes its killing power as well as its characteristic red color.

Solutions of lime-sulfur were first used as stock dips; they were tried as insecticides in California in 1886; and have, since about 1902, been a standard remedy for controlling certain scale insects, particularly the San José scale. These solutions are also efficient fungicides, and are used in a large number of combinations. They are very disagreeable to use because of their caustic properties, which cause them to burn the face, eyes, and hands of the operator, and because of their odor. They should never be used with soaps or with soap-oil emulsions without stabilizers.

Lime-sulfur solutions can be made at home by cooking together fresh or stone lime and sulfur. A number of formulæ are in use, of which the following is typical:

Lump or stone lime	50 pounds
Commercial ground sulfur	100 pounds
Water, enough to make	50 gallons

Heat about one-third of the required amount of water and to this add the lime. As soon as the lime starts slaking, add the sulfur, which should have been previously mixed thoroughly with enough water to make a thick paste. Then add the remainder of the water and boil for from 45 minutes to 1 hour, adding more water as necessary to keep up to the original level. If cooked by steam, as is usually done, a mechanical agitator should be provided. When the free sulfur has all disappeared, the mixture should be strained and may be stored in barrels, tanks, or cisterns.[1]

In order to use lime-sulfur solutions intelligently, their strength, or concentration, must be tested. This is done by means of a hydrometer,

[1] See *Ill. Agr. Exp. Sta. Cir.* 277, Fig. 2, 1928.

an instrument that works on the principle that any object will sink in any liquid until it displaces its own weight of that liquid. The lighter the liquid, the deeper it will sink; the heavier the liquid, the higher it will float. The stem of the hydrometer is graduated to make measurements easy. Two standard scales of graduation are used, *the specific gravity scale*, which begins at 1, for water at 70° C., and the *Baumé (Bé.) scale* which begins at 0 for water at 70° C. The correspondence between these two scales and the method of testing lime-sulfurs are shown in Fig. 164.

The concentrated home-boiled and commercial lime-sulfurs must always be diluted. Different batches of the home-boiled preparations will vary somewhat in strength. The many brands of commercial lime-sulfur on the market usually test about 33° Bé. The 33° material should be diluted, 1 part to 7 or 8 of water, for use as a dormant or winter spray on fruit trees; or about 1 to 49 of water for a summer spray. The following dilution table has been worked out to indicate the number of gallons of lime-sulfur at any strength that should be used to make 50 gallons of spray, for the different purposes specified, and also the proportion of water to use to 1 part of the lime-sulfur of any strength.

As lime-sulfur which has been drawn from different levels in storage tanks or barrels will give varying readings on the hydrometer, it is best to test the diluted spray mixture when ready to be applied rather than to depend on a dilution table. When the application is to be made to dormant trees, *the diluted lime-sulfur mixture should give a reading of about* 5° *on the Baumé hydrometer, or* 1.035 *specific gravity* (see Fig. 164). *For summer spraying, the reading should be slightly less than* 1° *Bé., or about* 1.005 *specific gravity* (see Fig. 164).

Dry Lime-sulfur.—There are a number of dry powdered materials on the market as substitutes for the liquid lime-sulfur. Dry lime-sulfur is liquid lime-sulfur with nearly all of the water removed. The chemical content of the material is slightly changed during the drying. Tests by several experiment stations indicate that these materials are about as effective as liquid lime-sulfur when mixed so as to give the same content of sulfur in the dilute spray that occurs in liquid lime-sulfur. If made to contain the same amount of sulfur as liquid lime-sulfur, the materials are much more expensive. It is also troublesome because of the amount of sludge in the dilute material. On the other hand, they are much more convenient to ship, store, and handle than liquid lime-sulfur.

Sodium sulfide and barium sulfide are two sulfur compounds sold under the trade names of "Soluble Sulfur" and "B.T.S." They have about the same efficiency as dry lime-sulfur. Sodium sulfide should never be used with arsenate of lead.

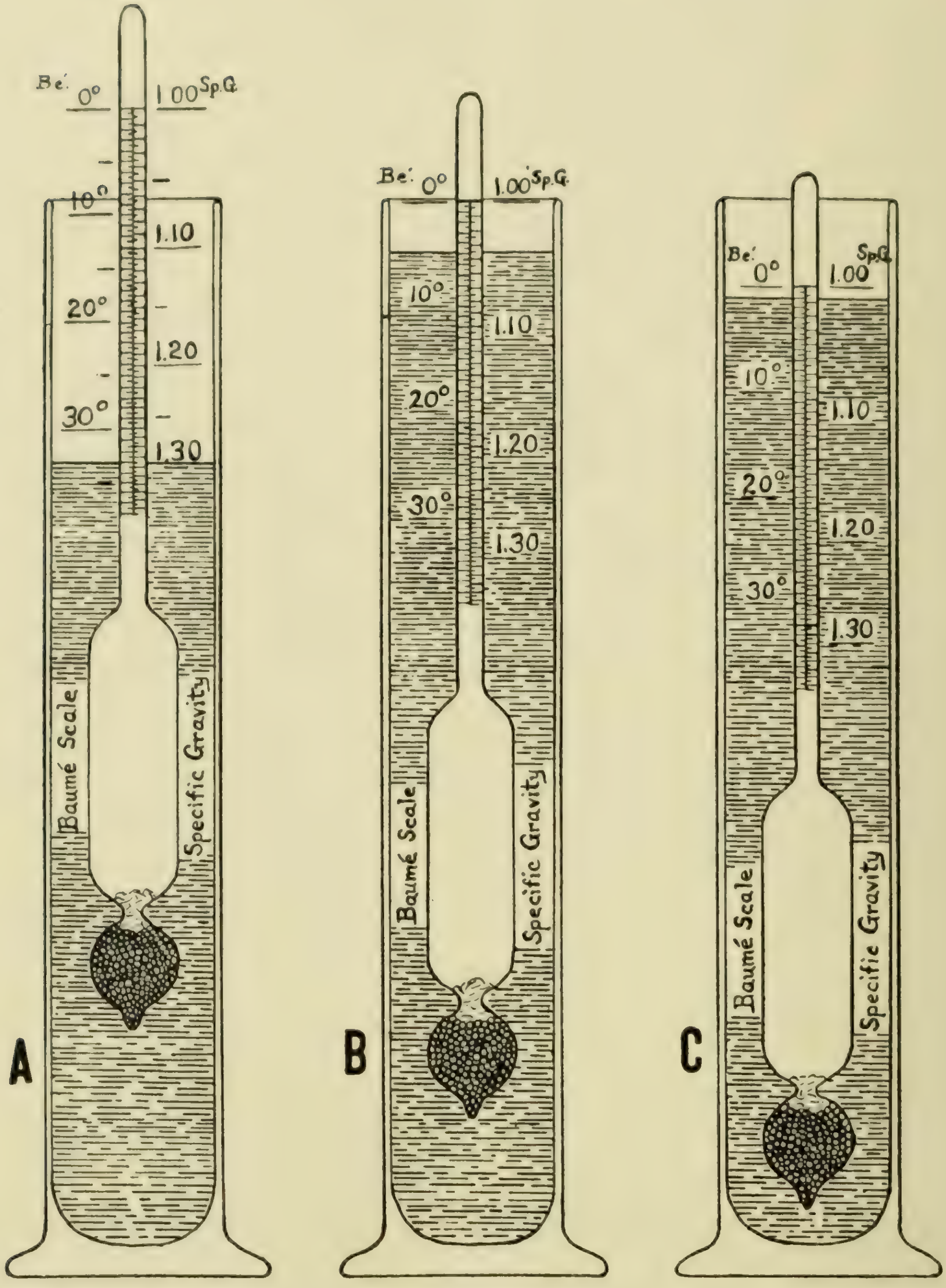

FIG. 164.—Diagrams showing how to test lime-sulfur solution with the hydrometer. *A* shows the way in which the hydrometer should float in good, full-strength, commercial lime-sulfur; *B*, the way it should float in lime-sulfur properly diluted for winter or dormant spraying; and *C*, how the hydrometer should float in lime-sulfur properly diluted for summer spraying. The type of hydrometer in common use gives the Baumé reading in a scale on the left side and the specific gravity reading in a scale on the right side of the spindle. Note that the smallest units on the Baumé scale are ½° while the smallest units on the specific gravity scale are 0.005. (*Original; drawing by R. D. Glasgow.*)

Table XI.—Dilution Table for Concentrated Lime-sulfur Solutions

When the hydrometer reads:		To make a winter or dormant spray for San José scale or pear-leaf blister mite (should test about 5° Bé., when diluted)		To make a summer or foliage spray for apples, pears or cherries (should test slightly less than 1° Bé., when diluted)	
Degrees Baumé	Specific gravity	Use the following parts of water to one part of the lime-sulfur	Use the following number of gallons of lime-sulfur to make 50 gallons of spray	Use the following parts of water to one part of the lime-sulfur	Use the following number of gallons of lime-sulfur to make 50 gallons of spray
36	1.330	8 1/10	5 1/2	56 1/7	7/8
35	1.318	7 7/10	5 3/4	56 1/7	7/8
34	1.306	7 1/3	6	49	1
33	1.295	7	6 1/4	49	1
32	1.283	6 7/10	6 1/2	43 1/2	1 1/8
31	1.272	6 2/5	6 3/4	43 1/2	1 1/8
30	1.261	6 1/7	7	39	1 1/4
29	1.250	5 9/10	7 1/4	39	1 1/4
28	1.239	5 2/3	7 1/2	35 2/5	1 3/8
27	1.229	5 1/4	8	35 2/5	1 3/8
26	1.218	4 9/10	8 1/2	32 1/3	1 1/2
25	1.208	4 7/10	8 3/4	29 3/4	1 5/8
24	1.198	4 2/5	9 1/4	25 2/3	1 7/8
23	1.188	4 1/8	9 3/4	24	2
22	1.179	3 4/5	10 1/2	22 1/2	2 1/8
21	1.169	3 1/2	11 1/4	21 1/4	2 1/4
20	1.160	3 1/6	12	19	2 1/2
19	1.151	3	12 3/4	18	2 5/8
18	1.142	2 7/10	13 3/4	17	2 3/4
17	1.133	2 1/2	14 1/2	15 2/3	3
16	1.124	2 1/4	15 1/2	14 1/3	3 1/4
5	1.036	0	50	4	10
1	1.007	Too weak	Too weak	0	50

Typical analyses of some of these dry substitutes for liquid lime-sulfur are as follows:

	Dry lime-sulfur	Sodium sulfide	Barium sulfide
Active ingredients...	......83 to 80%	......85%	......82%
	CaS_5 and CaS_4. 70–63%	Na_2S_4..... 56%	BaS_4....... 68%
	CaS_2O_3........ 5%	$Na_2S_2O_3$.. 25%	BaS_2O_3..... 6%
	Free sulfur.... 8–12%	Free sulfur 4%	Free sulfur. 8%
Inert ingredients...	.... 17–20%	.... 15%	.... 18%

Oils.—Oils of different classes have been very extensively employed as insecticides, and their use is rapidly increasing. The mineral oils

derived from crude petroleum are those most generally used for contact insecticides, although vegetable oils, such as linseed oil and corn oil, and animal oils, such as fish oil, also are useful. The mineral oils may be divided into two groups: (1) The *light oils* with boiling points from 150 to 550° F., such as gasoline and kerosene and some fuel oils; and (2) the *heavy oils* with boiling points above 550° F., generally known as lubricating oils and some crude oils.

Oils are sometimes used undiluted for combating mosquitoes in water, certain parasites on animals, and for spraying to kill insects where no attention need be given to the effect on plants. Unfortunately they are very toxic to plants, and to prevent this injury in most cases oils are used in the form of emulsions. The emulsions are generally made, by agitation, with soap and boiling water, or by the so-called cold-mixed method where the emulsion is made with the aid of some colloidal substance, such as Bordeaux mixture, calcium caseinate, gelatin, or certain gums and clays. In any case the emulsifier forms an extremely thin layer about each minute oil droplet, and thus, changing the interfacial tension between the two liquids, prevents the oil droplets from coalescing. The more widely used oil emulsions are lubricating-oil emulsions, crude-oil emulsions, distillate-oil emulsions, and kerosene emulsion.[1]

Lubricating-oil Emulsions.—These emulsions were first used by the federal Bureau of Entomology for the control of citrus scale insects. During the past few years they have been further developed by several of the state experiment stations. They are now used extensively in combating scale and other insects on deciduous-orchard and shade trees and some truck crops. There are several formulæ in general use. One which has given good results is:

Light-grade lubricating oil[1]	1 gallon
Water	1 quart
Potash fish-oil soap or potash vegetable-oil soap	1 to 2 pounds[2]

[1] The oils giving the best results are those within the following limits:
Volatility at 110° C. for 4 hours, not over 2 per cent,
Viscosity at 100° F., 90 to 250 seconds (Saybolt test),
Specific gravity at 20° C., 0.87 to 0.93.
[2] The amount of soap depends upon the hardness of the water.

The water, soap, and oil are placed in a kettle or other receptacle and heated to a boil, and then pumped twice, at a pressure of 75 to 250 pounds, through a spray pump having the disc removed from the nozzle. Make sure that all the mixture passes through the pump twice. The mixture must not be allowed to cool before pumping.

For making the stock emulsion on a large scale, an all-metal pump is necessary. For small amounts a barrel pump may be used. The stock emulsion is best cooked by steam. It should not be made in a

[1] *Bull. Illionois Nat. Hist. Sur.*, Vol. 17, Art. V, 1928.

cooker which has previously been used for cooking lime-sulfur, without a thorough cleaning. It should not be stored in lime-sulfur barrels. The cooker may be a barrel or tank with a steam coil in the bottom having small apertures through which live steam is emitted into the mixture of soap, water, and oil.

Lubricating-oil emulsions are made also by pumping together oil and certain substances, such as Bordeaux mixture, calcium caseinate, milk powder, and certain colloidal clays and gums.

Distillate-oil Emulsions.—These emulsions are used principally for the control of pear thrips. The U. S. Bureau of Entomology recommends the following formula for making a stock solution of this emulsion.

Boiling water	12 gallons
Fish-oil soap	30 pounds
Raw distillate oil, 30 to 34° Bé	20 gallons

Pour the boiling water into the spray tank and add the soap while the agitator is running. As soon as the soap is dissolved, pour in the oil slowly, continuing the agitation. After the oil has been allowed to mix thoroughly, pump the material, under a pressure of 175 pounds, through fine nozzles and store in clean receptacles.

Miscible Oils.—There are many, so-called "miscible oils" on the market which are used for the control of scale and other insects requiring a strong contact spray. They are mainly mixtures of vegetable or mineral oils with vegetable- or fish-oil soaps. They readily emulsify with water to form a milky, white fluid. The commercial miscible oils are usually diluted about 1 part to 15 to 40 parts of water, according to the directions given by the various manufacturers, and used as dormant sprays for scale insects.

The miscible oils can be prepared at home in the following manner, as recommended by the Washington Experiment Station (*Bull.* 184, 1924):

	By Weight, Per Cent	*By Volume, Per Cent*
Lubricating oil	90	91
Cresoap	10	9

Cresoap, the name here given to the cresylated fish-oil soap emulsifier, is made by dissolving 5 parts by volume of potash fish-oil soap in 4 parts of cresylic acid or technical cresol. By weight the proportions are 5½ to 4½. The soap should contain no free alkali and should have 30 per cent of moisture. When the soap is mixed with the cresol, the emulsifier becomes fluid and will dissolve at once in the oil. Soda soap or weak potash soap should not be substituted for the potash fish-oil soap specified here. Several other oils are used to a limited extent in making emulsions for special purposes, such as crude carbolic acid, creosote oil, linseed oil, and some others.

Kerosene emulsion was formerly widely used for a contact insecticide, but because of injury to plant foliage it has been largely replaced by other emulsions. The formula in general use in this country is:

Soft water	1	gallon
Laundry soap	½	pound
Kerosene	2	gallons

The soap is dissolved in the water by boiling, the kerosene is added immediately on removing the water from the fire, and the mixture pumped vigorously for about 10 minutes through a spray pump. It is then diluted with water to the desired strength.

Soaps.—Most soaps when dissolved in water at sufficient strengths have value as contact insecticides. Potash fish-oil soaps are the most widely used for this purpose. Potash vegetable-oil soaps are of equal merit and do not have such a disagreeable odor. Sodium soaps are hard soaps, or laundry soaps, and are used chiefly as stickers or spreaders. Fish-oil soap, or whale-oil soap, at about ½ pound to 1 or 2 gallons of water was formerly used for many soft-bodied insects and at 2 pounds per gallon of hot water, for dormant spraying for scale insects, but has been supplanted to a great extent by the more effective oil emulsions, lime-sulfur, and nicotine. Certain vegetable-oil soaps, particularly soybean-oil soap, have been found of value in the control of insects. Soaps are now used chiefly in the preparation of emulsions and as spreaders for nicotine sprays.

Derris.—The tropical plants of the family Papilionaceæ (*Deguelia* spp.) have been employed for many years as fish poisons. They are quite extensively used in England as insecticides. The roots and bark are dried and powdered and used, mixed with some diluent, as a dust, or are extracted in water and used as sprays. They act both as stomach and contact poisons, and are used in several proprietary insecticides. Derris has been recommended for aphids, for lice and fleas on domestic animals, and as a wash for killing ox warbles in the backs of cattle. Some of the commercial preparations of derris have about the same killing power on aphids as nicotine sulfate. They should be used at the strengths recommended by the manufacturers.

Fumigants

(See Table XII)

Poisons in the form of gases used to kill insects are called fumigants. Their application is generally limited to plants or products in tight enclosures. Fumigants are used to combat both piercing-sucking and chewing insects. They are employed largely for insects that infest houses, mills, stored grain and seeds, the holds of ships, greenhouses, growing trees where spraying is not practicable, the underground trunks and roots of growing trees, the soil, nursery stock, and plant and animal products, especially those imported from foreign countries or from areas where some serious crop pest, not generally distributed, is known to

TABLE XII.—FUMIGANTS TO BE USED FOR INSECTS IN ENCLOSURES

Fumigant	Dosage per 1,000 cubic feet	Killing power	Specific gravity	Penetration	Danger from fire	Effect on plants	Special cautions	Cost of materials per 1,000 cubic feet	Best uses
Hydrocyanic acid gas[1] (for stored products)	12 ounces of 88 per cent calcium cyanide	Very high	0.9483	Slight	None	Kills	Poisonous to moist foods	75¢ to $2	For mill and household insects
Hydrocyanic acid gas[1] (for greenhouse)	¼ ounce of 48 per cent calcium cyanid	High	0.9483	Slight	None	Use with caution	Must not be breathed; use at night	2¢	For greenhouse insects
Carbon bisulfide	10 pounds	High	2.63	Good	Very inflammable	Kills	Use caution with seeds	$1 to $2.50	For stored grains, clothes moths and carpet beetles
Carbon tetrachloride	40 pounds	Very weak	1.583	Fair	None	Kills	Use caution with seeds	$2 to $5	Where there is danger from fire
Nicotine 40 per cent (for greenhouse)	¼ fluid ounce	Good	......	Slight	None	Safe	None	2¢	For greenhouse aphids
Sulfur dioxide (burning sulfur)	4 pounds	High	1.433	Good	Safeguard generator in which sulfur is burned	Kills	Tarnishes, bleaches, taints food, prevents germination	10¢ to 75¢	Few
Naphthalene	100 pounds	Fair	......	Slight	None	Kills	Taints food; kills seeds	$5 to $25	For household insects
Paradichlorobenzene (for household)[2]	100 pounds	Fair	1.267	Good	None	Kills	Taints food; use caution with seeds	$25 to $50	For household insects

[1] Hydrocyanic acid gas may be generated from calcium cyanide; or from sodium cyanide, water and sulfuric acid; or from liquefied hydrocyanic acid, p. 256.
[2] For the use of paradichlorobenzene against the peach tree borer, see page 598.

exist. Where fumigants are to be used for insects infesting living plants, great care must be taken that the gases may not injure the plants. Dry food substances are not damaged by the common fumigants, but those containing much water may be poisoned. As is the case with contact and stomach poisons, very few gases have been found that are effective as killers of insects, that are not also toxic to the plants.

General Directions for Fumigating.—Regardless of the kind of fumigant to be used, great care is required to make the enclosure to be fumigated as nearly airtight as possible. In dwellings, greenhouses, mills, and storerooms, all cracks, broken glass, chimney holes, ventilators and other openings must be very tightly closed. Strips of gummed paper or even 4-inch strips of newspaper, soaked in water, will be found useful to paste over cracks; pieces of wallboard, cut to fit, for large openings; and rags or cotton waste for small holes. More failures in fumigation are due to insufficient preparation of the building than to any other cause.

Fumigations of living plants should ordinarily not be attempted unless the temperature of the air surrounding them is between 40 and 80° F., and for greenhouse plants the best temperature is between 55 and 68° F. Where no plants are involved, the temperature should be above 70° F. Fumigating should be done when there is little or no wind. When living plants are to be fumigated, it is safest to do the work at night, since sunlight during, or within an hour before or after, fumigating causes injury to the plants.

The length of exposure to gas where no living plants are involved should be from 6 to 12 hours, and may be prolonged without injury. Where plants are being treated, the length of exposure must be very carefully correlated with the dosage, and unless otherwise specified should not be longer than 1 hour.

It is the duty of anyone undertaking fumigating to familiarize himself thoroughly with the procedure and to safeguard from injury persons living in adjoining rooms or apartments and to prevent anyone from entering the enclosure being treated.

Before fumigating any building, provision should be made for ventilating it after the fumigation is over. If a gas mask, correctly charged for the particular gas being used, is available, it is exceedingly useful in setting off the charge and for entering the building afterward to open doors and windows. Otherwise several doors or windows must be arranged so they can be opened *from the outside*.

The dosage for fumigants is proportioned to the number of cubic feet in the enclosure. Consequently the first step in fumigating is to determine the cubical contents of the enclosure. If separate rooms or several floors are to be treated, it is best to generate the exact amount of gas needed in each room, and separate measurements and calculations should

be made for each. The following directions for determining the cubical contents of a greenhouse are taken from Weigel and Sasscer, *U. S. Dept. Agr. Farmers' Bull.* 1362, 1923.

To determine the cubical contents of an even-span greenhouse (Fig. 165 *left*), compute the number of square feet in the rectangle, *a*, and in the right-angle triangles, *b* and *c*, and multiply the sum of the three by the length of the greenhouse.

For example: $a = 5 \times 20 = 100$ square feet; $b = 5 \times 10 \div 2 = 25$ square feet; $c = 5 \times 10 \div 2 = 25$ square feet; $a + b + c = 150$ square feet; 150 square feet $\times$ 100 feet (length of house) = 15,000 cubic feet, the cubical contents of the greenhouse.

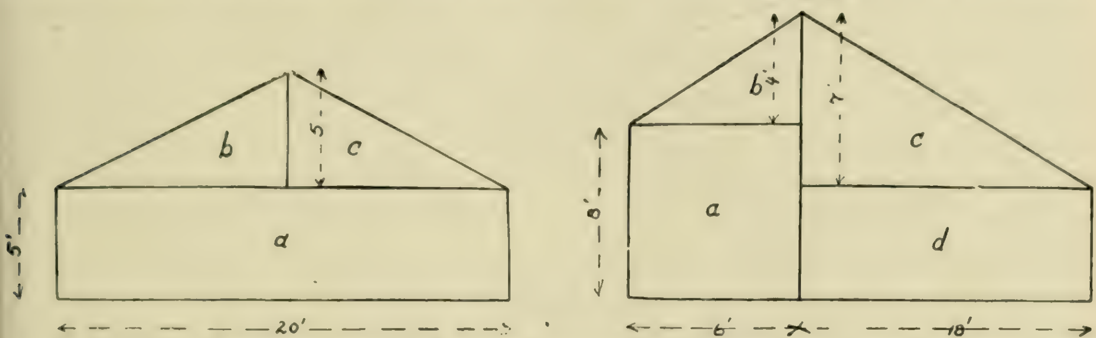

FIG. 165.—Diagrams showing how to compute the cubical contents of a greenhouse. At the left an even-span greenhouse; at the right a three-quarter-span greenhouse. (*From U. S. D. A. Farmers' Bull.* 1362.)

To determine the cubical contents of the three-quarter-span greenhouse (Fig. 165, *right*), multiply the sum of the rectangles *a* and *d* and the right-angle triangles *b* and *c* by the length of the house.

For example: $a = 6 \times 8 = 48$ square feet; $d = 18 \times 5 = 90$ square feet; $b = 6 \times 4 \div 2 = 12$ square feet; $c = 18 \times 7 \div 2 = 63$ square feet; $a + d + b + c = 213$ square feet; 213 square feet $\times$ 100 feet (length of house) = 21,300 cubic feet, the cubical contents of the greenhouse.

In estimating the cubical contents of a greenhouse, it is not necessary to make allowances for the space occupied by the elevated benches and pots.

To determine the total quantity of fumigant to be used, multiply the number of thousand cubic feet contained in the greenhouse [or other enclosure] by the quantity of fumigant to be used per 1,000 cubic feet; for example, if ½ ounce cyanide is to be employed per 1,000 cubic feet, and the greenhouse contains 15,000 cubic feet, the total amount of cyanide necessary would be 7½ ounces.

Knowing the number of cubic feet in the enclosure, the amount of materials to use will depend further (1) on the dosage which experimentation has shown to be necessary to kill the particular insects under treatment and (2) *where living plants are involved*, upon the dosage which experience has shown can be used without burning those particular kinds of plants.

Hydrocyanic Acid (HCN).—Of the chemicals employed as fumigants for insects, hydrocyanic acid gas is by far the most extensively used. It is colorless and very slightly lighter than air, the specific gravity of the gas being 0.9483. It diffuses rapidly, but because it is lighter than air, the diffusion is mainly upward. The gas has a slightly stinging odor

somewhat like that of sparks from metal, described by some as resembling that of peach stones. It is readily soluble in water. It will tarnish such metals as brass, gold, or nickel, but the tarnish is easily removed by rubbing with a polishing cloth or prevented by coating them with vaseline. It has no effect on the colors of most fabrics or papers. It is not inflammable or explosive. Under normal atmospheric pressure, the gas does not readily penetrate closely packed materials, such as piles of grain, sacks of flour, rolls of cloth, or bales of cotton. This lack of penetration may be overcome by using the gas in a partial vacuum.

Hydrocyanic acid is one of the most deadly gases known, quickly killing animals, and also killing plants when used in too large doses or for too long exposures. Its action on animals is twofold, as it affects both the nerve centers and the respiratory organs. Extreme care is necessary in using this gas to prevent injury to the operator or others who may be exposed to its action.

Four methods are now used for the employment of this gas:

(1) By the use of calcium cyanide (see p. 257).

(2) By the so-called liquid method where the hydrocyanic acid gas is liquefied under pressure and stored in steel containers, from which it can be liberated as desired. One pound of liquid hydrocyanic acid is sufficient to treat 3,000 cubic feet in well-built mills or dwellings.[1]

(3) By the pot method, where the gas is generated in earthenware jars placed within the enclosure to be fumigated. This is usually done by mixing sulfuric acid and water in the container and then adding the desired amount of sodium or potassium cyanide.

(4) By generating the gas by the use of sulfuric acid on sodium or potassium cyanide in solution, in a special chamber or machine, and introducing the gas into the enclosure to be fumigated through tubes leading from the machine.[2]

The first two methods are the most recent but are largely replacing the others where fumigating with this gas is a common practice.

The pot method is being rapidly supplanted by calcium cyanide dust but a brief description is given for those who may still wish to use it. A number of 3- or 4-gallon, glazed earthenware or stone crocks or paraffined wooden containers of sufficient capacity so the contents do not come within 4 inches of the top, must be provided as generators. If filled, some of the contents will spatter out, through the action of the chemicals. Not more than 5 pounds of cyanide should be used in one generator, and there must be at least one for each room. The generators should be placed at intervals over the enclosure, depending on its size, and the proper amount of water placed in them. The correct amount of acid

[1] See *Calif. Agr. Exp. Sta. Bull.* 308, June 1919; and *U. S. Dept. Agr. Farmers' Bull.* 1321, July, 1923.

[2] See *U. S. Dept. Agr. Farmers' Bull.* 1321, 1923.

should then be carefully poured into the water. Considerable heat is generated by the reaction of the acid and water, and unless the generators are of good grade, they may break, which may result in the burning of floors or injury to the operator. The cyanide should then be carefully weighed into paper bags, which should be placed beside the containers. Having everything in readiness, the operator should quickly drop each bag into its generator, starting with those farthest from the exit, and at once leave the room. If more than one floor of a building is to be treated, the fumigation should start on the upper floors.

Following fumigation and immediately after ventilating, the residue remaining in the containers should be removed, and buried or poured into the sewer. The cyanide used should be of c.p. grade. Cyanide containing more than a trace of sodium chloride, or sodium nitrate, is not suitable for fumigation purposes. The dosage of hydrocyanic acid gas required for different insects will be given in the discussion of control measures for these insects.

For fumigation where the treatment of living plants is not involved, the usual proportions are, *for each* 100 *cubic feet of space:*

Water	3 fluid ounces
Commercial sulfuric acid (specific gravity 1.83)	1½ fluid ounces
Sodium cyanide[1] (98 per cent pure)	1 ounce

In the treatment of living plants, the proportions used are about the same but the dosage is greatly reduced. For greenhouse plants the following formula is generally sufficient *for* 1,000 *cubic feet.* This dosage may have to be reduced if very tender plants are to be treated, or increased for very resistant insects:

Water	½ fluid ounce
Commercial sulfuric acid (specific gravity 1.83)	¼ fluid ounce
Sodium cyanide[1] (98 per cent pure)	⅛ ounce

Calcium Cyanide ($Ca(CN)_2$).—This form of cyanide has been on the market as an insecticide for only a few years. It is lower in cyanide content than sodium or potassium cyanide. One form in common use contains from 40 to 50 per cent calcium cyanide and gives off its gas very slowly. It will give off about half as much hydrocyanic acid gas as an equal amount by weight of sodium cyanide. Another form of dust contains 88 per cent calcium cyanide and will yield about 90 per cent as much gas as an equal weight of sodium cyanide. In this form of dust the gas is generated very rapidly upon exposure to the air. *No acid is required to generate the gas from calcium cyanide dusts, the necessary reaction taking place when it is simply exposed to the atmosphere.*

Calcium cyanide has been used for killing scale insects on citrus trees, by blowing the calcium-cyanide dust into tents placed over the trees. For

[1] Potassium cyanide is now little used in fumigation. About one-fourth less hydrocyanic acid gas is given off where this form of cyanide is used.

household insects, mill insects, and greenhouse insects the proper amount of the dust is spread out, not over 1/8 inch thick, on newspapers, or on the floor, or on the walks in the greenhouse. It is used very extensively for the control of rodents by placing or blowing a small amount of material into their burrows. This material has also been used in combating chinch bugs to kill the bugs trapped by barriers.

The dosage to be used will depend upon the nature of the materials to be treated, the tightness of the building or other enclosure, and the kind of cyanide dust used. With an 88 per cent calcium-cyanide dust, 3/4 pound to each 1,000 cubic feet of space is recommended for dwellings, mills, etc., and 1/8 ounce per 1,000 cubic feet is a kind of minimum dosage for ordinary greenhouse fumigation. With a 48 per cent dust the dosage should be about twice the above recommendation.

In greenhouse fumigating it is recommended that the above dosage be tried in an experimental way. If a satisfactory kill is not secured, the dosage should be gradually increased, provided no burning results. If the plants are injured, the dosage must be reduced. The correct dosage for particular plants and insects can be determined by consultation with the state or station entomologist.

Carbon Bisulfide (CS_2).[1]—The commercial grade of carbon bisulfide which is generally employed for insecticide work, is a nearly colorless, ill-smelling liquid that changes to a gas very rapidly when exposed to the air. The gas is 2.63 times as heavy as air, and therefore sinks to the bottom of any container in which it is used. The gas does not discolor fabrics, but the liquid leaves a yellowish residue. It is highly inflammable and explosive when mixed with air, and for this reason, must be used with caution. A flame of any kind, a lighted cigar or even the spark from hitting metal on metal, or from an electric switch may cause an explosion of the gas. Because of the fire hazard, this chemical cannot be shipped by mail or express. In some cases, its use in buildings invalidates insurance policies.

The gas is deadly to all forms of insect life, if used at sufficient strengths and at temperatures in which the insects are active (70° F. or above). It is, on the whole, the best fumigant where much penetration is required, as for treating bins of grain or seed, or piles of feed that can be kept in a tight room or container. It is much used for treating houses infested with insects, for insects in soil, and for killing animals in their burrows. It is also used in the form of an emulsion for soil-infesting insects and other animals.

Carbon bisulfide cannot be used to treat growing plants. If breathed by man, the gas causes dizziness and nausea, and produces somewhat the effect of intoxication. It is deadly if inhaled in large amounts.

[1] Also called *carbon disulfide*.

To use this gas, first have the sides and bottoms of the bins, rooms, or containers to be fumigated as nearly airtight as possible. Where there is sure to be some leakage, the amount of carbon bisulfide must be increased above that given below. Never attempt to fumigate a room or bin with large cracks or openings in the bottom or sides. The best results will be obtained at temperatures from 75 to 90° F. Do not fumigate when the temperature is below 60° F. One pound of carbon bisulfide to each 100 cubic feet of space is usually sufficient. The liquid may be applied directly to grain or seeds, but this may injure germination, and better results will be obtained by pouring the carbon bisulfide on gunny sacks or rags or cotton waste placed in the container. This gives a rapid evaporation which is more effective than when the liquid is exposed in pans. While not necessary, it is better to cover the tops of open bins with a tarpaulin or blanket. Keep the room or bin closed from 36 to 60 hours. Such exposure will not injure the milling qualities of grain or the germination of most seeds and will leave no poisonous residues on feeds.

Sulfur Dioxide (SO_2).—This gas is used to some extent as an insecticide, but is not generally as effective as those already discussed. It is usually generated by burning sulfur that is dampened with alcohol, or sulfur candles which may be purchased ready prepared for burning. The dosage used is from 2 to 6 pounds per 1,000 cubic feet, varying with the insect and material to be treated. Sulfur dioxide is non-inflammable, but corrodes metals and discolors some fabrics. It is slightly heavier than air, having a specific gravity of 1.433. This gas destroys the germinating power of most grains and affects the baking qualities of flour. It cannot be used on living plants. It has a very strong bleaching effect, which may be partly overcome by having the space to be treated very dry. The gas can now be obtained in liquid form, shipped in steel cylinders, which is the most convenient to use where any large-scale fumigating operations are to be undertaken.

Nicotine ($C_{10}H_{14}N_2$).—Nicotine is employed extensively for greenhouse fumigation. The free nicotine is the form generally used. The nicotine is volatilized by painting it on hot steam pipes, or by heating in shallow pans. It may be driven off from tobacco stems by burning them. Another method is to use commercial nicotine papers which contain a known amount of nicotine and liberate the nicotine by burning the paper. The paper should be damp enough to smoulder; if it burns readily, most of the nicotine will be destroyed. The fumigation is best done under humid conditions and at temperatures between 50 and 70° F. It should never be done during bright sunshine. No general rule for the use of commercial nicotine preparations can be given other than to follow the directions on the package.

Paradichlorobenzene ($C_6H_4Cl_2$).—This chemical, which may be purchased in the form of white, readily volatile crystals, is now widely used

as a soil fumigant for killing the larvæ of the peach-tree borer (see p. 598). The gas has a specific gravity of 1.267, and so will readily penetrate the air spaces in soils or the crevices in the underground parts of trees. It is employed to some extent in household fumigation, but imparts an odor to grains or foods. The gas is non-inflammable, and does not bleach or discolor metals or fabrics.

Other Fumigants.—Carbon tetrachloride, CCl_4, is a heavy gas with a specific gravity of 1.583, that is used to some extent for insect fumigation. It is not nearly so toxic to most insects as carbon bisulfide, requiring about four times as much to be effective. Because of the fact that it is non-inflammable, it can be employed in some situations where the fumes may come in contact with sparks or fire. Because of its low killing power, it is not of much value. Ethylene dichloride, $C_2H_4Cl_2$, has been recommended,[1] mixed 3 volumes with 1 volume of carbon tetrachloride, to form a non-inflammable, non-explosive, penetrating gas without bleaching or tarnishing properties, and not dangerous to human life. It should be applied like carbon bisulfide. From 12 to 14 pounds per 1,000 cubic feet have been recommended for a 24-hour exposure against insects of stored products. Chloropicrin, nitrobenzene, and mixtures of chlorine, carbon tetrachloride, ethyl acetate, and other gases have been used to some extent in insect fumigation. The use of these materials is still in the experimental state. Formaldehyde has been used as a fumigant for killing disease germs, but *is useless for killing insects.*

Repellents

Substances which are only mildly poisonous, or which may not be active poisons, but which prevent damage to plants or animals by making the food or living conditions of the insects unattractive or offensive to them, are called repellents. These substances are rarely, if ever, repellent to all kinds of insects. Such chemicals can sometimes be employed to advantage where it is impossible to use an insecticide, and may afford a greater or less degree of protection to manufactured products, growing plants, or the bodies of animals.

Bordeaux Mixture.—While primarily a fungicide, Bordeaux mixture is quite repellent to many insects, such as flea beetles and leafhoppers, when sprayed over the leaves of plants. By the addition of arsenate of lead, a poisoned Bordeaux is made that is widely used as a preventive of, and a remedy for, insects and plant diseases on many crops. It is to some extent an ovicide and contact poison for leafhoppers.

Bordeaux mixture is made at different strengths for different purposes. The strength is generally indicated by numbers, as 3–5–50 or 2–4–50, of which the first number designates the number of pounds of copper

[1] See *Jour. Econ. Entomol.*, Vol. 20, pp. 636–639, August, 1927.

sulfate and the second the number of pounds of lime to be mixed with 50 gallons of water. The formula for the widely used 3–5–50 mixture is as follows (any other strength desired can be made by varying the amounts of lime and copper sulfate:)

	Field Formula	*Garden Formula*
Water (cold)	50 gallons	3 gallons
Hydrated lime	5 pounds	5 ounces
Pure copper sulfate (bluestone)	3 pounds	3 ounces

For controlling chewing insects, the above mixture is generally poisoned by adding:

Arsenate of lead	1 to 2 pounds	1 to 2 ounces

Where it can be secured, unslaked, stone or rock lime can be used instead of the hydrated lime; 3 pounds to 50 gallons of water, or 1 ounce to 1 gallon, is sufficient. Air-slaked lime should never be used. Only wooden, earthenware, or glass containers should be used for mixing and storing Bordeaux. For making small amounts, it is best to suspend the proper amount of copper sulfate in a sack near the top of a tub, barrel, or spray tank containing about three-fourths of the water to be used, the evening before spraying is to be done. If this has not been done, the sulfate can be dissolved quickly in a little hot water and then diluted with cold water. Quickly-dissolving powdered copper sulfates can be purchased from most dealers for use instead of the crystal form. Slake the lime, or mix the hydrated lime, in a small quantity of water, dilute it, and then pour the lime water into the copper sulfate solution and stir vigorously. The arsenate of lead may then be stirred up with a little of the Bordeaux and added to the mixture, together with enough water to make the full amount. For small gardens it is more convenient to buy one of the commercial Bordeaux but these are not generally as effective as the freshly mixed material.

If much spraying is to be done, stock mixtures of lime water, and copper sulfate solution, should be prepared. These can be kept indefinitely in covered jars or, if not tightly covered, by adding water to keep up to the original level. These stock solutions are best prepared by dissolving 1 pound of copper sulfate to each gallon of water and by mixing or slaking lime and then diluting it so that each gallon contains $1\frac{2}{3}$ pounds of hydrated lime (or 1 pound of stone lime). Do not mix the two solutions until ready to spray. Never mix them without first diluting one or both. When ready to spray, fill the spray tank about three-fourths full of cold water. If you want a 3–5–50 Bordeaux, add 3 gallons of the lime-water stock mixture (representing 5 pounds of lime) to each 50 gallons that the spray tank will hold. Start the agitator of the pump going, or stir vigorously, and pour in 3 gallons (representing 3 pounds) of the copper-sulfate stock solution for each 50 gallons the spray tank will hold. Continue

agitation or vigorous stirring for several minutes. If the Bordeaux is to be poisoned, add the arsenate of lead, reduced to a thin paste, and more water as necessary to make a full tank. To make good Bordeaux observe the following precautions: (*a*) Do not allow the bluestone solution or the Bordeaux to stand in contact with any metal; (*b*) use only pure lime and bluestone; (*c*) have one of the chemicals diluted with nearly all of the water before the other is added; (*d*) use water as cold as possible; (*e*) agitate thoroughly after mixing; and (*f*) use within a few hours after mixing. If spraying is interrupted, the mixture can be preserved for a day or two by adding 2 or 3 ounces of sugar to each 50 gallons and stirring thoroughly.

Creosote and Coal Tar.—These complex chemical substances and their derivatives, such as naphthalene and carbolic acid, are very repellent to certain insects, particularly to the chinch bug, adult clothes moths, and certain flies and beetles. Thin lines of creosote poured on the ground have been used extensively in the Middle West for diverting the migrating hordes of chinch bugs when they leave the small-grain fields for the corn. These substances are also used in treating wood to render it distasteful to certain boring insects, especially termites.

Strong soap solutions mixed with creosote or carbolic acid are repellent to the adults of certain wood borers. Nearly any very fine dust, such as road dust, air-slaked lime or soot, acts as a repellent to leaf-feeding insects. Certain oils, such as kerosene, castor oil, fish oil, oil of tar, pine oil, rosin oil, oil of pennyroyal, oil of citronella, lemon oil, oil of tansy, and several others are used, alone or in combination with other chemicals, to protect the bodies of animals or seeds from insects. Powdered alum, camphor, and turpentine, are also employed for this purpose. Repellents do not kill insects unless used in combination with traps, and have to be renewed frequently, as the insect attack recurs.

Physical or Mechanical Control

Aside from the destruction of insects that may be accomplished by *ordinary* farm practices (see below) there are certain *special* physical or mechanical measures that are of value. The more important of these are outlined on pp. 229 and 230.

The destruction of insects or their egg masses by hand is sometimes the most practical method to employ. In other cases it is possible to prevent the invasion of a crop by migrating insects, through the use of physical barriers. The crawling hordes of chinch bugs and army worms may often be stopped by constructing deep, dusty-sided furrows around the fields toward which they are traveling. The same result may be achieved by using barrier lines of certain heavy-bodied oils, poured along

on the ground. Screening of houses has come to be a regular practice in all civilized countries as a protection from flies and mosquitoes and the diseases they carry. Sometimes seed beds, fields, or vineyards are protected by covering them with screens of thin cloth. Because of the expense involved, this measure can be resorted to only in cases where the crop has a high money value. Sticky bands around tree trunks are often employed against insects that infest trees by climbing up the trunks; they are of no value for insects that fly into the trees to feed or to lay eggs. Fly nets, muzzles, and other similar devices are of some value in protecting animals from certain insect parasites.

Cranberries are protected from some of their insect enemies by flooding the bogs at the proper time, and some other crops, in areas where irrigation is possible, are protected in the same way. The draining of swamps, marshes, and other standing water is the most effective method of destroying mosquitoes and horseflies.

Mechanical devices, such as hopperdozers, hoppercatchers, aphidozers, fly traps, moth traps, maggot traps, light traps and others have been used successfully for catching and killing a variety of insects. These will be discussed further under the insects for the control of which they have been found most useful.

The Use of Low Temperatures.—Artificial heating or cooling of stored products, or the mills or factories where such products are processed, is a common method of preventing insect damage. Nearly all insects become inactive at temperatures between 60 and 40° F. Few insects are killed at these temperatures unless exposed to them for a considerable length of time. Insects in hibernation frequently withstand temperatures of -20 to -30° F., or lower. It is not certain that exposure to such temperatures will kill the eggs of such species as the grain weevils. But practically no damage from insects will occur at temperatures below 40° F. Low temperatures are not as effective as high temperatures in killing insects, but storage of food products or clothing at points below or near freezing will prevent all insect damage. Changes from low to high temperatures and back to cold are more effective in killing insects than constant low temperatures.

Superheating.—Careful experiments by a number of entomologists have shown that no insect can long survive when exposed to temperatures of 140 to 150° F. Most insects, including those which attack stored grains, are killed by 3 hours' exposure to temperatures from 125 to 130° F., and this, or a slightly longer exposure, will destroy all stages of these insects. Many mills and large elevators have equipped their buildings with enough heating pipes to enable them to raise the temperature to 125 to 150° F. for several hours during periods of warm weather, and thus kill all insects in the buildings at a much less expense than by fumigating.

There are a number of heat-treating machines now on the market which raise grain to a high temperature while it is being passed through them. Such machines are fairly effective in cleaning infested grain and other seeds, but the exposure of the grain to high temperature must be of sufficient duration to kill all stages of the insects. It should be understood that the heat-treatment of grain will cause a certain shrinkage due to loss of moisture.

In applying heat to piles of clothing, bins of grain, or bales of goods, it must be borne in mind that it requires a long time for the heat to penetrate, and that the temperature on the surface will have reached the killing point long before the insects within the material have been affected.

Cultural Control or the Use of Farm Practices

In a state of nature, the plants growing on the land in any of the great agricultural areas of the world are quite different from those which are grown after such lands have been placed under cultivation. There was in most of these areas a predominance of grasses, but with a mixture of legumes, and plants of many other botanical families. Such plants grew from year to year with little change in the proportion of one over the other. The insects depending on these wild plants were always assured of a food supply sufficient to maintain them, but, with the exception of a few general feeders, not abundant enough to permit a great increase of any one species.

Under farming conditions great changes take place in the character of the plants grown on the land. There are no longer a great number of species, generally intermixed, but a few species occupying the land in nearly pure stands of thousands and hundreds of thousands of acres. This affects the insect population of the land in two general ways. Many of those which depend on the plants of one family, or even on one species of plant, find their food supply cut off, except in the small uncultivated areas and may nearly, or quite, disappear from the region, as certain species of billbugs in drained bottom lands. Others take to the cultivated crop closely related to their wild food plant, and find it perhaps more palatable. Such insects may, and generally do, increase enormously and become very destructive, as have the chinch bug and the cotton-boll weevil.

Among insects that injure cultivated crops, the number of general feeders is quite small. Those which feed on the plants of one family, or even on those of one species, are numerous. The following lists of the principal insect enemies of corn, wheat, and clover in Illinois, were recently made up by several of the entomologists working in that state, and include only those insects that are of sufficient importance to be

considered as doing commercial damage to these crops. Under each crop, the pests are listed in the order of their destructiveness to this crop in Illinois.

TABLE XIII.—A COMPARISON OF THE MOST IMPORTANT INSECTS ATTACKING THREE MAJOR FIELD CROPS IN ILLINOIS

Corn Insects	*Wheat Insects*	*Red Clover Insects*
Northern corn rootworm	Hessian fly	Clover-bud weevil
[1] White grubs	[1] Chinch bug	Clover-leaf weevil
[1] Wireworms	Wheat jointworm	[2] Grasshoppers
[1] Chinch bug	Wheat-stem maggot	Clover-root curculio
Corn earworm	[1] Wireworms	Clover-seed chalcid
[1] Southern corn rootworm	[2] Grasshoppers	Pea aphid
Corn root aphid	[2] Army worm	[2] Variegated cutworm
[2] Army worm	Wheat-head midge	Clover-seed caterpillar
[2] Grasshoppers	Wheat-stem sawfly	Clover-seed midge
Black cutworm	Wheat sawfly	Green clover worm
Seed-corn maggot	[1] Billbugs	Clover leaf tyer
Common stalk borer	Frit fly	[2] Army worm
Sod webworm	Wheat-head army worm	Clover-root borer
[1] Billbugs	English grain louse	Clover-stem borer
Morning-glory flea beetles	Green bug	Leafhoppers
Corn-seed beetles	Sorghum webworm	
Carrot beetle	[1] White grubs	
Corn prionus	False wireworms	
Clover rootworm	[1] Southern corn rootworm	
Corn leaf aphid	[2] Variegated cutworm	
Imbricated snout beetle		
Pale-striped flea beetle		
Thief ant		
Green June beetle		
Fall army worm		
[2] Variegated cutworm		

[1] Species of importance to corn and wheat only.
[2] Species of importance on clover, wheat, and corn

Crop Rotation.—In the above list, it will be noted that 8 of the insects which are listed as pests of corn, are also listed as pests of wheat, but that only 3 of the 50 insects are serious pests of all three of these crops. Wheat and corn are grasses, clover is a legume; and it will be seen from a study of these lists that much can be accomplished in preventing insects from becoming seriously abundant in our fields, if a good rotation is practiced where a crop of one plant family follows that of a different family. It is not possible in many cases in grain-farming areas to put such a rotation into effect in all fields each year; but a large part of the increased yields obtained from a rotation where grains follow legumes, and legumes grains, is due to the reduction in insect damage. Crops of the same kind, such as corn, oats, and wheat, grown on the

same land, year after year, give a condition favorable to the insects that attack the grass crops; and the same is true of a number of years' cropping of ground with plants of any one family.

Because of the ease with which most insects move about, many of the species which feed on any crop will be found in the fields the first year they are planted to such a crop, and may occur in numbers sufficient to cause severe damage. For this reason, rotation of crops cannot be depended upon for combating all insects attacking field crops. Generally, however, infestations in such fields will be later and lighter than in fields continued in the same crop, and crop rotations are by far the best, and in some cases almost the only, means we have of controlling certain insects. The application of rotations to the control of different species will be discussed in more detail under the insects attacking certain crops.

Cultural Methods.—Much can be accomplished in the control of some crop insects by cultivating the soil at a certain time of the year or in some special manner. The best method to employ will depend on the life history and habits of the species to be controlled. Deep, thorough, and frequent cultivation of fields infested by the corn root aphid and its attendant ant is the best method of freeing the soil of these insects. Some species of insects that go through a part of their development in the ground can be easily killed if the soil is cultivated while they are in their pupal cells; the plum curculio is an example. Others may be killed in the same way in the hibernating shelters in which they pass the winter; for example, the oriental fruit moth. Some degree of control may be obtained over certain insects by planting infested land to row crops which require frequent cultivation; white grubs and certain fleabeetles are examples.

Infestation may sometimes be entirely prevented, if the ground is kept in a state of clean cultivation during the egg-laying period of some of the crop-infesting insects, like the southern corn rootworm, that will not deposit their eggs on the bare soil. Certain other species, as the pale western cutworm, prefer the bare ground, and with these, cultivation should be avoided until after the eggs have been laid. With some of the soil-infesting insects such as white grubs, plowing at a certain time in the year will destroy large numbers of the larvæ, or aid in their destruction, by exposing them to birds and other animals that feed upon them; while plowing at other times will be of no value in reducing their numbers.

Destruction of Crop Residues.—The destruction of crop residues is often of great importance in insect control. In some sections of North America where the European corn borer is well established, it has become necessary to practice rotations and cultural methods that permit the utilizing, plowing under, or destruction by burning during the fall, winter

or early spring, of all crop residues and weeds remaining in the fields. In many of the states infested by the European corn borer such a clean-up of all corn refuse has been made compulsory.

In order to control insects by rotation of crops, or cultural practices, it is necessary that one understand the life history and habits of the insect with which one is dealing. A control that would be effective against one kind of insect, might be useless against a closely related kind because of a difference in habits. These operations, to be effective, must also be used at the proper stage of the development of the insect. It is useless to try to destroy white grubs by late fall or winter plowing, after they have gone down a foot or more below the surface of the soil, or to kill insects by burning their hibernating places, before they have entered them in the fall or after they have left them in the spring.

Variations in the Time of Planting and Harvesting.—The time of planting a crop has a very great influence on the infestation of the crop by some insects. Early-planted corn will largely escape injury by the corn earworm in most sections of the country. On the other hand, early-planted corn may be heavily infested by the southern corn rootworm or the European corn borer. In places where both kinds of these insects are present, the best time of planting corn will depend to a considerable extent on which of these insects is the more destructive.

There is no better example of the importance of farm practices on insect control than the effect on the infestation by the Hessian fly of early and late seeding of wheat. During most seasons early-sown wheat will be moderately to heavily infested, and medium-late-sown wheat will not be seriously infested. Indeed, there are many years when a difference of a few days in the time of seeding will make the difference between a good crop and a very poor one, all because of the difference in the amount of infestation by the Hessian fly (see p. 359).

The following table shows the average yields of wheat and the average infestation by Hessian fly obtained in an 8-year experiment from fields at eight different points in Illinois. The first column shows the average yield obtained from all seedings made before the normal, safe-seeding date; the second column the average yield from approximately the same number of seedings made after the normal safe-seeding date. The third and fourth columns show the average percentage of plants which were infested by Hessian fly, when examined on Nov. 10 each year; the third column giving the infestation in all seedings made before the safe-seeding date for the particular locality, and the fourth column the infestation in all seedings made after the safe-seeding date. In each locality each year there were from three to five seedings at intervals of about 5 days before the normal safe-seeding date, and a corresponding number at similar intervals after that date.

Table XIV.—Average Yields of Wheat and Percentage of Infestation by the Hessian Fly

Location of field	Average yield		Average per cent of infestation	
	From wheat sown *before* the safe-seeding date, bushels	From wheat sown *after* the safe-seeding date, bushels	In wheat sown *before* the safe-seeding date, per cent	In wheat sown *after* the safe-seeding date, per cent
Rockford, Ill	21.8	28.1	24.5	1.7
Bureau, Ill	27.4	32.9	45.5	5.2
La Harpe, Ill	30.8	36.5	38.0	1.8
Urbana, Ill	29.5	37.1	32.6	5.4
Virden, Ill	23.6	28.4	48.0	6.3
Centralia, Ill	14.5	21.9	81.0	8.0
Carbondale, Ill	21.5	23.9	16.0	1.0
Grand Chain, Ill	15.5	21.4	32.3	1.0
Average	23.1	28.8	39.7	3.8

The Use of Resistant Varieties.—Some strains or varieties of cultivated plants are more or less resistant to certain of the insects that attack them. It is only by taking advantage of this resistance of the American grape roots to the grape phylloxera, which is native to North America, that we are able to grow European grapes in this country or in most of the large vineyard areas of Europe. By grafting these varieties on to American rootstocks, the injury is avoided. There is some very good evidence to show that a marked difference exists in the resistance of different varieties of grain to attacks by insects. Some varieties of corn and sorghums have been found to resist the attacks of chinch bugs. Extensive research along this line suggests the possibility that resistant varieties of corn may help to solve the problem of European-corn-borer control. On the whole, very little work has been done to develop varieties or strains of plants that are resistant to insects. This field offers possibilities that warrant more careful investigation.

Biological Control: The Introduction and Encouragement of Natural Enemies

The fact that man has, during the last few centuries, learned something about the habits, ecology and interrelations of insects, now enables him to take sides in the constant warfare that insects are carrying on against each other. The facts at hand concerning the insect population of a given area of the earth show that more than two-thirds of the species present are feeders on plants, or plant products,

or in other words, are competing with man for the products of the soil. From one-fourth to one-third of the insects present in any given area feed on other insects, and many of these are of great benefit to man in reducing the plant-feeding species. Others feed on those that attack the plant feeders, and so become the enemies of man. This complicated relationship of man and insects has already been discussed in Chapter II.

Parasitic and Predaceous Insects.—It has been found possible in many cases greatly to reduce the numbers of plant-destroying insects by introducing their insect enemies. One of the best-known examples is the reduction of the numbers of the gypsy moth in the New England states by the introduction of its insect parasites and predators from Europe and Asia. The reduction of the cottony cushion scale on the citrus trees in California by the introduction of the Australian lady beetle is the example most often quoted (see p. 57). Many other examples could be given. The results accomplished by this method of insect control have been so great that it has now come to be looked upon as one of the most effective means of reducing insect damage. This is especially true in cases where the damage is being caused by an introduced species of insect, whose natural enemies have not been brought with it to that part of the earth where it has become established.

There are certain points which should be kept in mind in regard to this type of insect control. There is no hope of *exterminating* insects by this method, and it is seldom possible so to reduce them that no other control measures need be used. When any parasite becomes so abundant that it nearly wipes out a plant-feeding species, it too must suffer a marked decline in numbers because of the reduction of its food supply. A scarcity of parasites permits the plant feeder again to increase until the parasite once more overtakes it. Thus where we have a single active parasite of an insect species, we will have more or less regular periods of abundance and scarcity of the parasite and its host. During the periods of its abundance, it will be necessary to depend on artificial measures for controlling the plant-feeding insect.

The aim in the employment of parasitic insects is, where possible, to find parasites for all stages of the plant-feeding species and have their attack so distributed that the host is never free from them in any life stage, and so cannot become destructively abundant. In the case of most plant-feeding species, it has not been possible to find such a combination of parasites. There are many plant-feeding insects which are never reduced by parasites below the point where they are capable of causing commercial damage to the crops on which they feed. The codling moth, San José scale, and white grubs may be taken as examples. In introducing a parasite into a locality where it has not been previously known to occur, great care must be taken. First, it must be ascertained without question that the insect to be introduced is a parasite on the particular

insect it is desired to control, or on other plant-feeding species; second, that it is never by any chance a plant feeder; and, third, that it will not attack some of the other primary parasites already present in the locality and so do more harm than good. These, and many other points, must be carefully investigated before the introduction of the parasite is attempted.

The establishment of the parasite is often attended with great difficulty, especially if it has to be brought from a distant part of the world, or from the southern to the northern hemisphere. A very high degree of skill in the handling of parasites has been developed by some entomologists in the laboratories where this work is under way.

A summary of the results obtained from the introduction of parasitic insects would show that this work has reduced insect damage in many cases, and while we cannot depend on parasites to control completely most of our destructive insects, the introduction of parasites has been one of the significant contributions of entomology to the advancement of agriculture.

The Use of Insect Diseases.—Insects, like other animals, suffer from the attacks of disease. At times, under favorable conditions, a disease may become epidemic on a species of insect, and within a few days or weeks reduce the species from a point of great abundance to one of scarcity. The spread of an insect disease is so dependent on weather conditions, and other factors not controllable by man, that little progress has been made in the artificial spread of diseases for controlling insects. The facts now known, however, warrant further experimental work along this line.

Legislation for Insect Control

In the early days of agricultural development in this and other countries, plants and plant products were brought into, or sent out of, the country with little or no thought concerning the insect pests that might be transported along with them. In fact, it is only within the last half-century that any serious attempt at legislation to restrict the spread of insect pests has been attempted by any country. The introduction of the grape phylloxera from America to the vineyards of France, some time about 1860, caused such serious destruction in the French vineyards and in those in other European countries to which it was carried, that it became apparent something must be done to prevent the unrestricted movement of infested vines to all parts of the world. In 1881, representatives of many of the European countries in which grapes were extensively grown met and agreed on regulations restricting the movement of infested grape stalks. The spread of certain plant pests in the United States started the passage of insect legislation in this country about the same time. But it was not until 1912 that the United States had any adequate federal law to control the menace of foreign plant pests.

At present, there are four classes of insect legislation: (1) legislation to prevent the introduction of new pests from foreign countries; (2) legislation to prevent the spread of established pests within the country, or within the state; (3) legislation to enforce the application of control measures that have been found effective in preventing damage by established pests; and (4) legislation to prevent the adulteration and misbranding of insecticides.

Quarantine and Inspection Laws.—The Federal Horticultural Board, composed of representatives of the federal Bureaus of Plant Industry and Entomology and the Forest Service, was created by the Plant Quarantine Act of 1912 and has charge of federal regulatory measures dealing with insects and plant diseases. Such measures prohibit the movement of plants from foreign countries to the United States without a permit, and regulate the exportation of plants from this country to foreign countries, and the movement interstate of plants and plant products. Every state in the union now has in force regulatory measures forbidding the movements of certain plants into, or within the state, at least until such plants have been inspected; and in many cases requiring reinspection at the point of destination. It is illegal to ship nursery stock anywhere in the United States unless it is accompanied by a certificate of inspection, stating that it has been found apparently free from certain seriously destructive insect pests and plant diseases. The requirements as to freedom from given pests vary with the different states. At the present time, there is a concerted effort on foot to secure uniformity of the regulations for the movement of plant products throughout the country. It will, of course, never be possible to make out an absolutely uniform list of insects which will, or will not, be permitted to leave or enter different states, as a pest which is of great importance in the Southern states might not be able to exist in the states farther to the North, and *vice versa*.

Fully half of the insect losses suffered in the United States are caused by imported insects. It is impossible to give a list of these insects here, but a few of them may be cited as typical examples. These foreign pests include such notoriously destructive species as the gypsy moth, San José scale, cotton-boll weevil, codling moth, Hessian fly, alfalfa weevil, European corn borer, Japanese beetle, brown-tail moth, and at least a hundred others.

As previously stated, nearly all states have at present in force, regulations preventing the unrestricted movement of plant products, to guard, in so far as possible, against the importation and establishment of new pests. It has also been found necessary to establish regulatory measures preventing the general dissemination, through the sale of nursery stock, of pests known to exist within a state. While the San José scale is now established in practically all the orchard-growing districts in the country,

nearly every state still has in force, regulations preventing the sale of nursery stock known to be infested by this insect. Such legislation is no longer intended primarily to prevent the spread of the pest, but is chiefly to protect uninformed purchasers from buying trees seriously infested with this insect.

Whenever it seems necessary, in order to prevent the introduction or spread of any dangerous insect or plant disease, the federal government has the power, after a public hearing, to prohibit the importation or shipment, interstate, of any class of plants or plant products from any foreign country or locality and from any state or portion of a state or territory in this country. Such specific prohibitions are called *quarantines.* Many of the states, also, have quarantine laws.

In general, it may be said of quarantine measures that the enforcement of such measures will check the spread of certain insects, but cannot be depended upon to stop such spread. A considerable expense is justified if the quarantine checks the spread of a new pest long enough to permit the development of control measures, the introduction of parasites, or changes in agricultural practices best suited to prevent loss by the newly established pest. It should be borne in mind, however, that regulatory measures are always expensive measures, and that it is impossible to keep a strong-flying insect out of adjacent territory from that at present occupied by it, merely by passing laws. It is certainly desirable that all reasonable restrictions be placed on the importation of new insect pests from foreign countries and that every precaution possible be taken to inspect plants and plant products entering this country, to see that they are free from foreign insects.

The history of an insect in its native country cannot always be relied on as a criterion of what the insect will do when established in some locality in another part of the world, where it is not held in check by the natural enemies found in its native home; and, for this reason, it is best from a legal standpoint to consider that all foreign plant-feeding insects and zoophagous parasites are dangerous, until they have been proved otherwise. At the present time, practically all civilized nations have in effect regulatory measures restricting the movement of plant products from other countries, and it is probable that these measures will become more strict in the future, rather than more lenient .

Compulsory Clean-up Measures.—While the regulations governing the control of pests in nurseries are, in most states, broad enough to allow for the enforcement of clean-up measures against orchard or field-crop insects, as well, it is only in comparatively a few states that such measures are generally enforced. Indeed, it usually requires serious loss of property or personal injury before the public will whole-heartedly back up such measures. Some of the eastern states, notably Massachusetts, have rigidly enforced the control of such pests as the gypsy and brown-

tail moths. If premises are infested in that state, the property owner is given legal notice that he must, before a given date, take measures to control certain insect pests. If such measures have not been taken before this date, the work is done by a force of men employed by the city or town in which the property is located. The cost of this work is assessed against the property in the form of a tax, and, if unpaid, constitutes a lien against the property as much as any other unpaid tax, and is collected in the same way. This measure has had a thorough test in the courts, and has now been in force for a number of years.

Insecticide Laws.—Aside from the legislation having to do directly with combating insect pests, or controlling their spread, many of the states have laws standardizing the grades of insecticides which are sold within the state. The federal Department of Agriculture, through the Insecticide and Fungicide Board, has in force a number of regulations governing the labeling, strength, and chemical composition of substances being imported or transported, interstate, as insecticides. For example, a substance offered for sale as an insecticide must bear a label stating the amount of arsenic it contains and what percentage of the arsenic is water-soluble; and either the name and percentage of each active ingredient and the total percentage of inert substances, or the name and percentage of each inert substance. It is also illegal to make claims for the efficacy of a material that cannot be substantiated or to sell a substance as a spray or dust if it contains anything injurious to plants.

B. NATURAL CONTROL

Natural control includes control (*a*) by climatic factors such as rainfall, sunshine, cold, heat, and wind movement; (*b*) by the physical character of the country, such as large bodies of water, mountain ranges, streams, the character of the stream flow, and the type of soil; (*c*) by the *natural* presence and abundance of predaceous and parasitic insects, birds, fishes, reptiles, and mammals and by cannibalism; and (*d*) by the presence of diseases which attack insects, and conditions favorable to the spread of such diseases.

Control by Climatic Factors

Under natural control, climatic factors are perhaps the most important. A few species of insects have become adapted to variations in climate to such an extent that they occur throughout the world, in temperate, and, in some cases, in temperate and tropical zones. Few, if any, species of insects occur in the arctic, temperate, and tropical zones, except such species as infest stored products, the dwellings of man, or the bodies of animals, and are therefore not subjected to a very marked degree to the climatic changes of any region.

As a general statement, it may be said that the insect life of a region is dependent, directly or indirectly, on the temperature of the region, the soil, and the amount of moisture. There are many species of insects which have become adapted to certain climatic conditions and thrive under these conditions even though they may seem at first to be unfavorable. Great numbers of mosquitoes and certain species of flies occur in the arctic regions during the brief summers. At the height of warm weather, the total number of insects in such regions is very large, but never, on the whole, as large as the numbers found in the tropics. Winter temperatures control the distribution of many insects; the harlequin cabbage bug, which cannot survive our northern winters, is an example.

A very warm, moderately humid, climate and fertile soil offer conditions favorable for the greatest development of insect life. A poor soil can support only a limited amount of plant growth, and therefore a limited insect population. A warm, wet climate is unfavorable to many insects. Such a climate creates a condition where insect diseases will flourish and also presents many physical factors unfavorable to insect life. A hot and very dry climate also is unfavorable, only a comparatively few species of insects having become adapted to live under desert conditions.

The amount of sunshine occurring in a given region also is important. Many species of insects are influenced to a marked degree by the rays of the sun. Some apparently seldom fly except during periods when the sun is shining; and, as flight is the chief means of dissemination of most species over any area, this is an important factor influencing the general abundance of insects; the chinch bug is one of the best examples.

Wind movement is also of great importance. Many of the smaller and frailer species of insects which normally fly for considerable distances are unable to leave the ground during strong winds, or if they do take flight, are so buffeted and beaten by the wind that they soon die; the Hessian fly is thus affected. Some species of insects, as certain mosquitoes, habitually fly against the wind while many others fly with the wind; their dispersal, or the direction of their dispersal, is to an even greater extent dependent upon wind movement at the time of year when they are in their winged or adult stage.

The brown-tail moth has spread very slowly in a westerly direction from the original point of establishment, but its spread to the east and north has been rapid, due chiefly to southwesterly winds during the time when the adults are flying.

Control by Topographic Factors

Large bodies of water, such as oceans, offer effective barriers to the natural spread of nearly all species of insects. Certain species that do not possess the power of flight are affected in their spread by smaller bodies of water, such as lakes or large streams, and are largely dependent

upon man or other animals for the passage of such barriers. The granary weevil is unable to fly, but has been carried by man over much of the earth. Mountain ranges also are effective barriers to the spread of insects and offer varying conditions of climate through which many insects cannot pass unaided. The Colorado potato beetle began spreading from Colorado to the East about 1859, and reached the Atlantic Coast in 15 years, while it was more than 50 years in crossing the Rocky Mountains. The character of the streams and the number of ponds and lakes control to a great extent the insect life of a country. Certain flies, mosquitoes, and beetles live in their immature stages in slowly moving streams or still water, while others, such as black flies and certain caddice-flies, live only in swift-flowing streams.

The character of the soil of any region exerts a marked influence over the insect inhabitants of that region. This is true not only because the soil has a direct influence on the plant growth of the region and thus indirectly affects the insects that live on plants, but also because many insects spend the whole or a part of their life in the soil. Certain soils are very favorable to their growth, while they would be unable to live in different soils, or in the same type of soil under different conditions. Certain species of wireworms live only in poorly drained soils, and certain species of tiger beetle larvæ, which live in sandy soils, are unable to exist in clay soils.

Control by Natural Enemies

Predaceous and Parasitic Insects.—Of the natural factors that tend to reduce the plant-feeding insects, the number of the insects feeding on other insects in a locality is sometimes as important as the climatic factors. It has been demonstrated many times that a plant-feeding insect removed to a part of the world where its insect enemies are not present, and with suitable food plants present, is able to increase to far greater numbers than was the case in its native home. Indeed it would probably be very difficult to produce crops in most regions of the earth, if the predaceous and parasitic insects were not present to keep down the plant-feeding species.

Weiss, in classifying the insects of New Jersey according to their food habits, found that 28 per cent of the approximately 10,000 kinds of insects known to occur in that state were feeders on other insects.

Cannibalism, the devouring of individuals by their own kind, is an important factor in reducing the numbers of certain insects. A conspicuous example is the larvæ of the corn earworm.

Birds.—From an insect standpoint a birdless country would be a highly desirable place in which to live, as in such a country they would be safe from the attacks of many of their most persistent enemies. A proportion of the food of most birds is made up of insects, and the food of

many species is largely of insect origin. The actual number of insects eaten in a day by certain birds is surprising, in some cases being almost or quite equal to the weight of the bird itself. This is especially true of the nestlings during the most rapid period of their growth. Thanks to the studies which have been carried on by the United States Bureau of Biological Survey, we now have sufficient data on the food of nearly all of the common species of birds to enable us to know their value as insect-destroyers.[1] Some of the common species, such as robins and catbirds, eat insects mainly during the summer when this kind of food is most abundant. Others such as some of the woodpeckers and creepers subsist largely on an insect diet throughout the year. Even those species that are largely grain feeders, such as the blackbird and English sparrow, will often congregate in large numbers in areas where insect outbreaks are occurring and will feed mainly on insects during the period when they can be easily obtained. See also p. 50.

While birds cannot be expected to become sufficiently abundant in any thickly settled farming area for us to depend upon them alone to prevent insect damage, they are of great value. Most birds earn, many times over, the fruit and berries they take from our orchards and gardens. The value of most birds as insect destroyers alone, will warrant all the protection we can afford them. This protection is needed not only against killing by the use of firearms and nest robbing, but also against the cat, which is the birds' worst enemy in many sections. The number of birds in a local area may be increased by providing food during the winter months and water and suitable nesting materials and places during spring and summer, and by planting seed- and fruit-bearing shrubs. The setting aside of tracts of land as game preserves also will aid in increasing the numbers of song birds valuable as insect destroyers.

Mammals and Other Animals That Feed on Insects.—Many of the small mammals feed to a great extent on insects. Some of the ground squirrels eat white grubs and other soil-infesting insects, but these make up only a small part of their food. Moles, shrews, and skunks depend largely on insects for their food, and destroy very large numbers of the soil-infesting kinds. Some species of snakes, newts, and salamanders also subsist largely on an insect diet. The toad is one of the most useful of our common small animals, its food consisting almost entirely of insects, more than 60 per cent of which are of injurious species. These are eaten in very great numbers, the toad devouring in 24 hours an amount of insect food equal to about four times its stomach's capacity.

Value of a Knowledge of Natural Control.—As the factors of natural control cannot be greatly influenced by man, it might seem that a knowledge of such factors would not be of much value. The opposite is true, however. Knowing the climate, soil, and topography of a region,

[1] Henderson, Junius, "The Practical Value of Birds," The Macmillan Co., 1927

we may, to a certain extent, be able to tell the kinds of insects that will be most common in that region, and, with a knowledge of their food plant preferences, the crops that will be most subject to injury. This is of the greatest value in estimating the amount of injury that may be expected from foreign insects newly established in a country.

This knowledge of natural control is also of great practical value in enabling one to tell the effect of the weather of a season on insects, and from this to predict the relative abundance of injurious species the next year. For example, a winter period of very low temperature with no snow will kill most of the eggs of the gypsy moth. Long periods of dry, hot weather, during the summer will prevent the apple maggot from ever becoming a serious pest in areas where such weather is the rule. Heavy rains during the time when the eggs of the chinch bug are hatching will often terminate a period of several years of serious destruction by this insect. In the case of the pale western cutworm, in the prairie provinces of Canada, it has been found possible, according to Seamans, to predict the irregular and very serious outbreaks of this cutworm, by noting the number of wet days in the preceding May and June. If there are fewer than 10 days in these 2 months when it is too wet to work in the soil, there will be an increase and probably an outbreak of the cutworm the following spring. If there are more than 15 such wet days in May and June, little trouble may be expected from this insect the following season. The explanation of this correlation between weather and cutworm abundance is as follows: The pale western cutworms work below ground except when the soil is wet. When driven above ground by heavy rains or by irrigation, they are attacked by several kinds of parasites, which reduce their numbers so that no outbreak is possible the following year. If the soil is dry enough so they may remain below ground most of their period of larval activity in May and June, the parasites do not reach them, the cutworms remain healthy, and may increase their numbers to epidemic proportions by the following year.

Taking into account what we know of the effect of various natural factors on insect abundance, it is now possible to warn growers of threatening outbreaks of certain of the more carefully studied species of insects, in time to apply measures of control. In Illinois, for example, during the past 10 years fruit growers have been informed, about 10 days in advance, the time when the eggs of the codling moth will start hatching. Field checks have shown that the predictions have usually been accurate to within 24 hours and that there has never been an error of more than 3 days. The importance of a knowledge of the effect of these natural factors on insect life is just beginning to be realized, and a more thorough study of them is badly needed.

CHAPTER X

APPARATUS FOR APPLYING INSECTICIDES

Probably the first apparatus for applying insecticides in liquid form was a bundle of twigs or feathers, or a brush broom. For applying dry insecticides, a bellows or blowing tube was used. Such crude apparatus was the only kind in general use up to less than 100 years ago. The development of spraying and dusting machinery has been largely an American achievement, of which we may be justly proud.

The two general methods of applying insecticides are: as *sprays*, in which water is the carrier for the poison; and as *dusts*, in which some fine dry powder is the carrier.

Spraying Machinery

A good sprayer is one that will apply a liquid to the surface of the object treated in such a manner as to give a uniform covering with the least expenditure of power, labor, and material possible to produce this result. In addition, a sprayer should have sufficient capacity to cover the objects to be treated in a short space of time. The period of time available for any one application depends on the kind of plants or insects being treated, but is not usually over 5 days. The sprayer must be strongly built and of the proper material to withstand wear and the chemical action of the spray mixtures. All working parts should be of brass or bronze. It must be so constructed that all parts are readily accessible for cleaning or making repairs. It must be as simple as possible in construction. A supply of spare parts should be available at some nearby point. It is best to buy of a reliable company whose machines have stood the test of practical work.

General Suggestions about Spraying.—No agricultural operation requires greater care and thoroughness than spraying. When stomach poisons are being applied, the aim should be to cover every bit of leaf and fruit surface and succulent buds and stems. If a contact insecticide is being used, it should be remembered that only those insects will be killed that are actually hit by the spray. While thoroughness is required, the application should be stopped as soon as dripping begins.

The application of sprays must ordinarily be very accurately timed to coincide with the period in the development of the insects when they are most easily killed, or the stage in seasonal development of the plant when it will best withstand the treatment. Since these times will vary widely

in different sections of the country, the grower should secure the advice of his own state entomologists regarding spray programs for different crops and insects. In general, the earlier the spray is given after the insects appear the easier it is to destroy them.

Spraying should not be done in rainy weather, although arsenical sprays will adhere satisfactorily to plants if the spray has time to dry before rain falls. Winter sprays should ordinarily not be applied when the temperature is below freezing or when the trees are wet with snow or rain.

Good pressure is essential to the best results in spraying and the spray outfit should be sufficiently powerful to maintain a pressure of at least 75

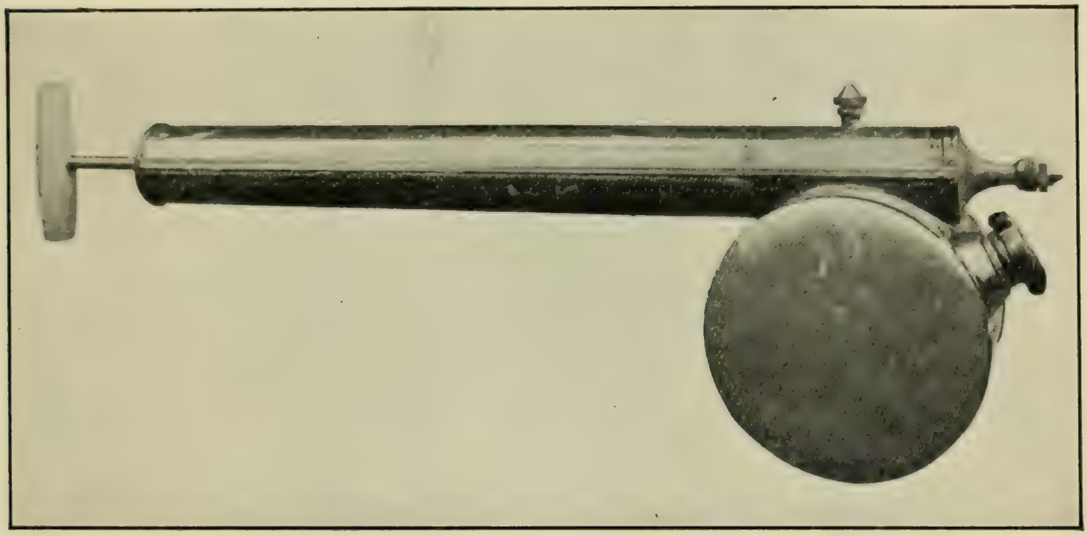

Fig. 166.—A hand atomizer, useful for spraying small plants. (*From U. S. D. A. Farmers' Bull.* 908.)

pounds. For orchard and vineyard spraying, best results are secured at pressures of at least 200 to 300 pounds per square inch.

When using arsenicals, which do not go into solution, good agitation of the spray material is very important to maintain an even mixture.

The best pump can easily be ruined by failure to give it proper care. Clean water should always be pumped through the sprayer after using, to flush out all of the corrosive and abrasive spray materials. Wooden tanks are best stored in damp places. The metal parts should be kept oiled to prevent rust.

Since most spraying materials are violent poisons, they should be plainly labeled and, together with mixing vessels, kept out of reach of children. Animals must be kept away from liquid sprays and not allowed to pasture under sprayed trees. Fruits and leafy vegetables must not be sprayed immediately before marketing unless a fugitive poison, like hellebore or pyrethrum, is used.

Kinds of Sprayers.—The size and type of sprayer to be used will depend on the amount and kind of work to be done, but the sprayer

FIG. 167.—A compressed-air sprayer, useful for a few plants or shrubs. (*From U. S. D. A. Farmers' Bull.* 908.)

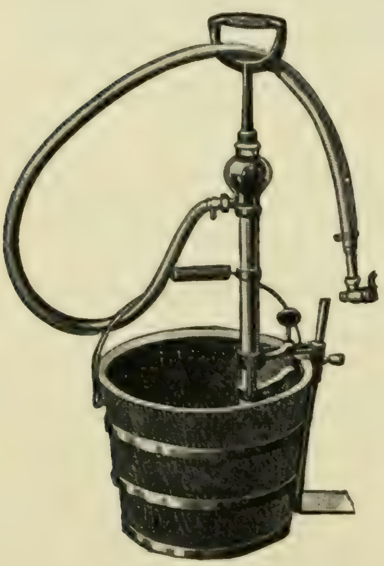

FIG. 168.—A bucket pump. (*From the Deming Manufacturing Co.*)

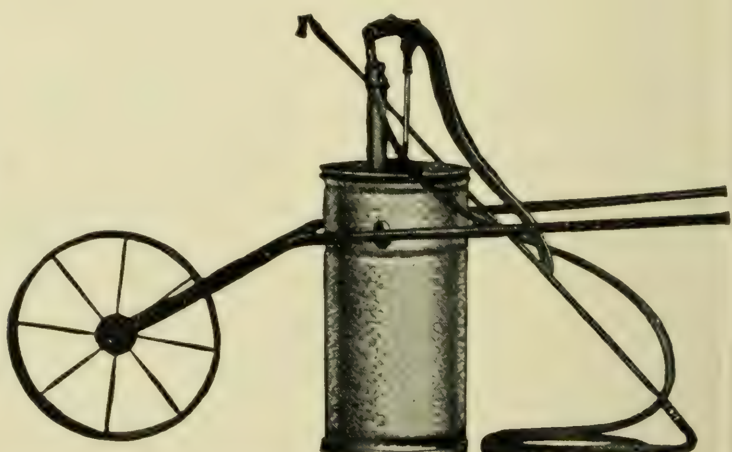

FIG. 169.—A wheelbarrow sprayer. (*From the Hardie Manufacturing Co.*)

should always be large enough. The engine for operating the sprayer should be able to maintain sufficient pressure without strain. Spraying,

at best, is a disagreeable task, and the use of a machine which does not have sufficient capacity is very likely to mean that the work will be poorly done.

The more important types of sprayers are (1) hand atomizers, (2) compressed-air sprayers, (3) bucket pumps, (4) wheelbarrow sprayers, (5) barrel pumps, (6) double-acting tank pumps, and (7) power sprayers.

For a few plants in a backyard garden or flower bed, a small sprayer of the atomizer type (Fig. 166) may be used. This type of sprayer is made in several styles. Those giving a continuous fine spray are to be preferred.

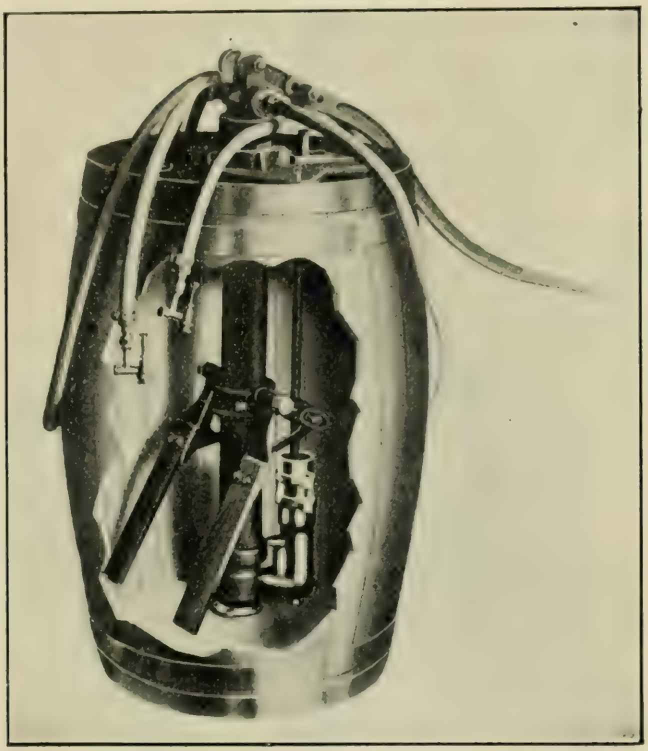

Fig. 170.—A barrel pump suitable for spraying a garden or small orchard. (*From U. S. D. A. Farmers' Bull.* 908.)

For the average garden, a good compressed-air sprayer of from 1 to 3 gallons capacity is fairly satisfactory. This type of sprayer (Fig. 167) should be equipped with a short extension rod and an angle nozzle. Such a sprayer may be used for covering a few shrubs, or bush fruits, but is not suitable for trees. There are several other types of hand sprayers suitable for use in small gardens such as the bucket pumps (Fig. 168), knapsack sprayers, and wheelbarrow sprayers (Fig. 169).

For large gardens of ½ to 2 acres, or for a small orchard for family use, a barrel sprayer (Fig. 170) with an extension rod at least 8 and not over 12 feet long is fairly effective. This sprayer should be so constructed that a man can maintain from 75 to 100 pounds' pressure, with one discharge pipe in operation. It should have a good agitator. The working

parts should be of brass or bronze. The air chamber should be in the barrel, not projecting much above the top, and sufficiently large to maintain an even pressure.

A tank outfit equipped with a double-acting, two-cylinder hand pump (Fig. 171) will be much more satisfactory for an orchard of from 20 to 40 trees. With this type of sprayer a pressure of from 100 to 125 pounds may be maintained, and while this is not sufficient for the best results, it will give fairly clean fruit, where the spray material is properly

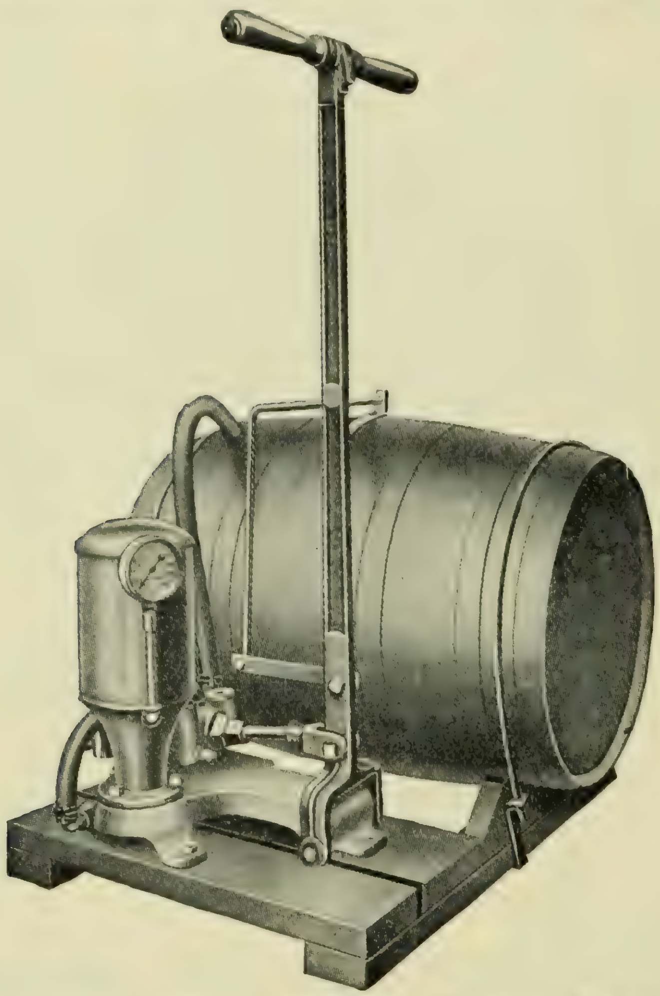

FIG. 171.—A double-acting, horizontal tank pump. (*From the Hardie Manufacturing Co.*)

mixed and thoroughly applied at the proper time. A lead of at least 25 feet of hose should be supplied.

For orchards of more than 50 large trees, a power sprayer (Fig. 173) is the only type that can be depended upon to give good results. There are many styles and makes of well-built power spray outfits on the market. In selecting the one best suited for any particular orchard, the points mentioned in regard to the essentials of a good sprayer should be kept in mind. The engine should, in all cases, be large enough to give an excess

of power for the kind of work to be done. This means that it should be capable of maintaining a pressure of 250 to 300 pounds. If extension rods are to be used, one should have at least 2 horsepower to each discharge pipe, and if the spray gun is used at least 3 horsepower for each gun. Most of the larger-type sprayers are now sold with engines of from 6 to 10 horsepower as standard equipment.

Parts of a Sprayer.—Some of the more important parts of a spray outfit are as follows:

The *cylinders* (Fig. 172) are the part of the pump in which the pressure is developed. They must be of non-corrosive material. Other things being equal, a cylinder of large diameter is to be preferred. The larger power pumps have 2, 3, or 4 cylinders.

The *plungers* or *pistons* (Fig. 172) force the spray liquid through the cylinders. The *plunger* is made to fit tightly inside the cylinder by means of *packing*. Some arrangement should always be provided for easily tightening or renewing the packing.

Valves, usually of the ball type, and *valve seats* (Fig 172) direct the flow of the spray. They are very likely to become clogged with particles of spray materials or dirt and *must* be readily accessible for cleaning.

An *air chamber* (Fig. 172) to equalize the pressure and remove the excessive strain should be provided on every pump. Its volume should be equal to at least half the capacity of the pump per minute. The discharge opening leading to the nozzles is located at the bottom of the air chamber.

The *tank* (Figs. 171 and 173), in which the spray ingredients are mixed and held, is usually of wood. Some small pumps use tanks of galvanized metal. Brass, although much more expensive, is resistant to all ordinary spray mixtures.

Since many spray ingredients are not soluble in water, an *agitator* (Fig. 172) is of great importance to keep the finely divided particles evenly distributed in the water.

A *pressure gage* (Fig. 171) is important to show under what pressure spray is being supplied to the nozzles.

Strainers, over the intake to the tank, and over the suction or intake pipe leading to the cylinders (Fig. 172), are of great importance in keeping the spray liquid free from troublesome foreign matter.

The *discharge pipe* should be as free as possible from abrupt angles that cut down the pressure between pump and nozzles.

The *hose* (Figs. 169 and 173) for orchard spraying should be at least 25 feet long, of ½-inch inside diameter and four- to seven-ply strength. For solid-stream forest-tree spraying, hose of much greater strength and size, and sometimes leads ½ mile long are required.

Each lead of hose is provided either with an *extension rod* and *nozzle* or with a *spray gun* or *solid-stream nozzle.*

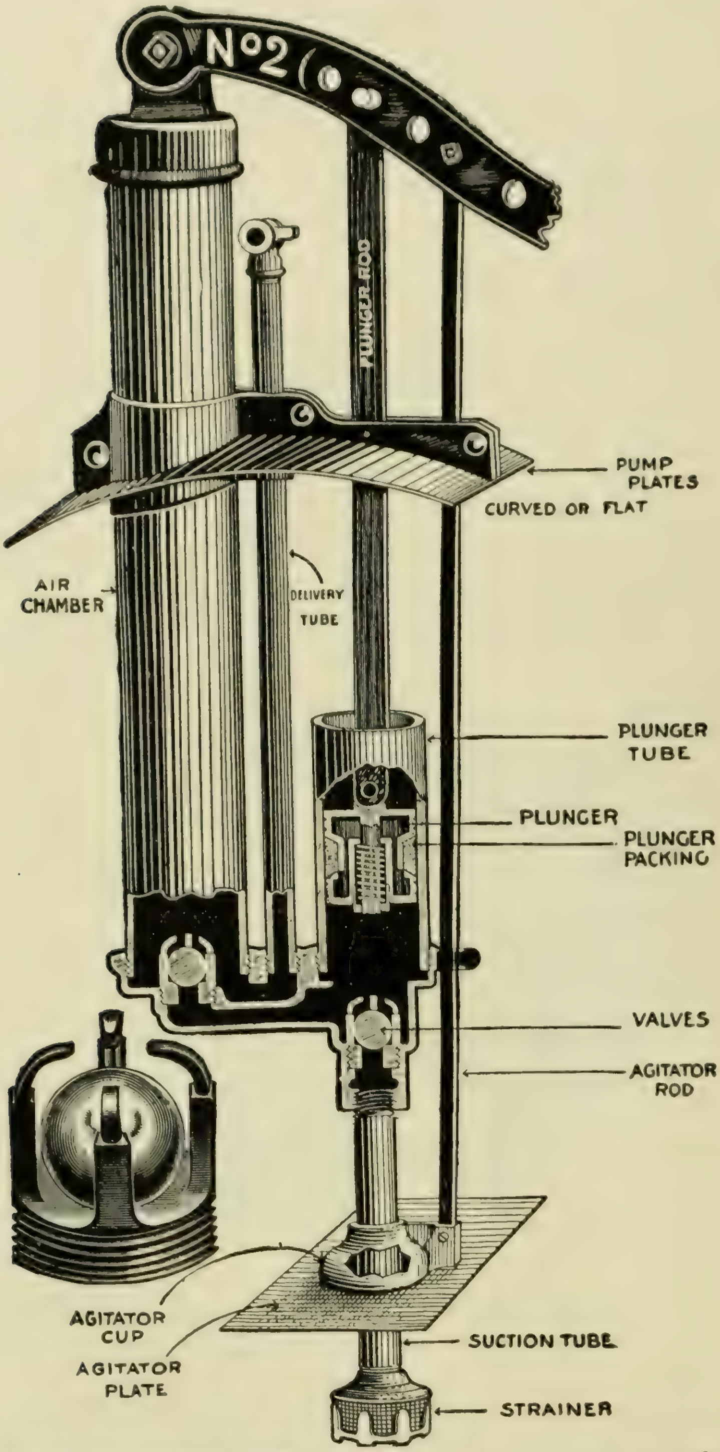

FIG. 172.—Sectional view of a hand pump to show arrangement of the valves, plunger and packing, and the course of the spray; with the principal parts named. The part labeled plunger tube is better known as the *cylinder*. (*From the Spramotor Company.*)

Nozzles and Spray Guns.—The actual application of the spray is usually made from an extension rod equipped with from one to three nozzles of one of several types, or with the spray gun. The latter has come into general use since about 1915. There is still a considerable difference of opinion as to its effectiveness.

The spray gun (Fig. 174) is made of a short, heavy rod about ¾ inch in diameter and 2 to 3 feet long with one or two large nozzles at the tip. The opening in the nozzles is rather large, and the gun throws a large

Fig. 173.—Motor-truck, high-pressure, power sprayer used for park and woodland spraying. The same motor drives the truck and operates the pump. (*From U. S. D. A. Dept. Bull.* 480.)

volume of spray. A rotating handle at the base enables the operator to regulate the stream, from a coarse spray that will carry to the tops of the trees, to a fine mist for the lower or near-by branches.

According to Anderson and Roth,[1] the following amounts of spray will be discharged from a spray gun with discs having different-sized apertures, and with a pressure of 250 pounds:

Size of Aperture, Inches	*Rate of Discharge, Gallons per Minute*
3/32	5
7/64	6
1/8	9
9/64	12
3/16	20

[1] Anderson and Roth, "Insecticides, Fungicides and Appliances," John Wiley and Sons, 1923.

Instead of a spray gun, an extension rod may be used to support the nozzles in spraying trees. Spray rods consist of light metal pipes, from 6 to 12 feet in length, with a cutoff at the base where they are attached

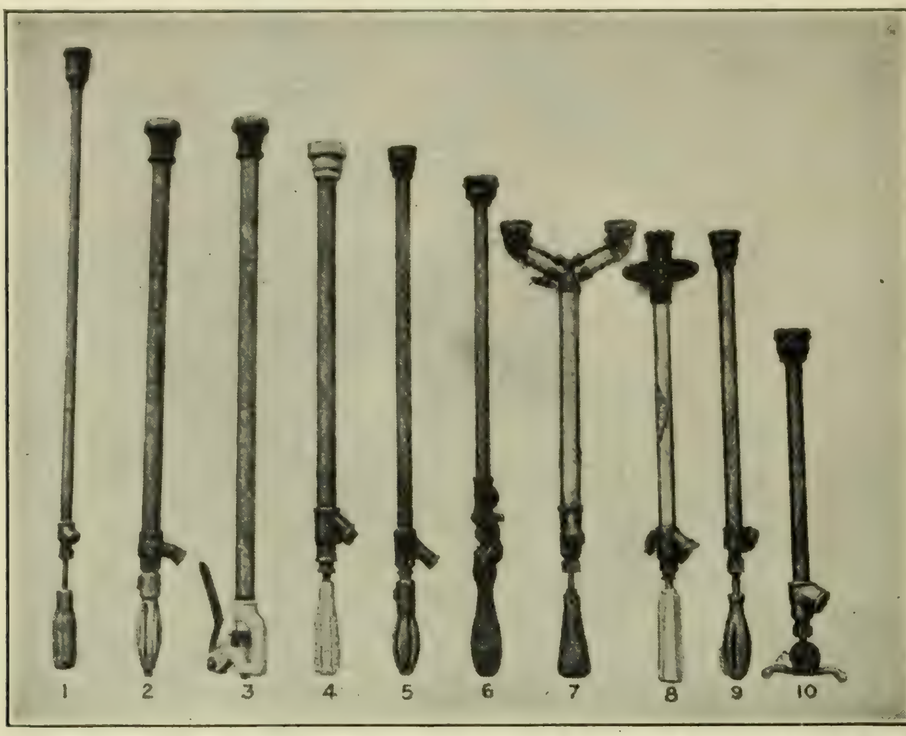

Fig. 174.—Ten different designs of spray guns. 1, Friend Universal; 2, Wardel (new design); 3, Wardelo; 4, Hardie; 5, Bean; 6, Myers; 7, Boyce; 8, Comet; 9, Hayes; 10, Friend. (From "*Insecticides, Fungicides and Appliances*" *by Anderson and Roth, John Wiley & Sons, Inc.*)

to the hose, and with one or more nozzles attached to the tips. The rods are generally made of light brass, enclosed in bamboo. Iron or steel rods are sometimes used, but are heavy and hard to hold.

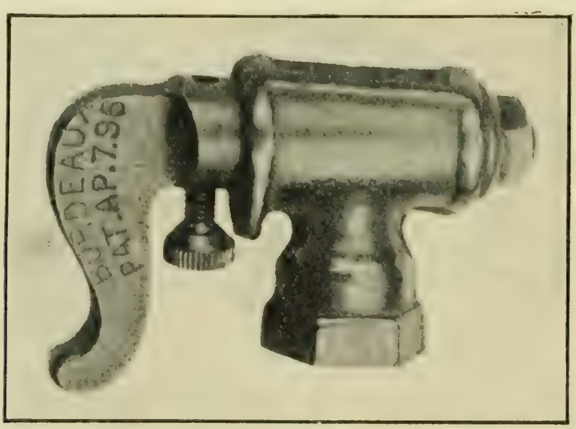

Fig. 175.—A Bordeaux nozzle, which throws a flat, fan-shaped, driving spray. (*From U. S. D. A. Farmers' Bull.* 908.)

Spray nozzles are of many styles, but may be grouped into four general types, the Bordeaux (Fig. 175), the Vermorel (Fig. 176), the disc type (Fig. 177), and the solid-stream type (Fig. 178). In the Bor-

deaux type, the stream is broken by a beveled obstruction, which may be set at any angle to the direction of the stream. This type of nozzle gives a driving, fan-shaped spray of rather coarse spray particles. It is very wasteful of spray material, is heavy, and wears rapidly where high pressures are used. It will drive the spray with considerable force

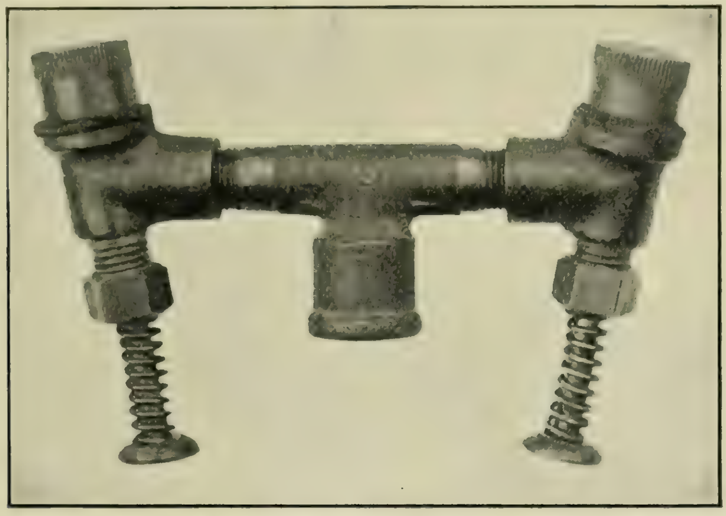

Fig. 176.—A double Vermorel nozzle with disgorger; each nozzle throws a misty cone-shaped spray. (*From U. S. D. A. Farmers' Bull.* 908.)

against the object to be sprayed, and this may sometimes be an advantage. This type of nozzle is now little used.

The Vermorel and disc nozzles consist of a cap enclosing a small chamber, called the *whorl chamber*. The spray enters this chamber at an angle through one or more openings and is discharged through a

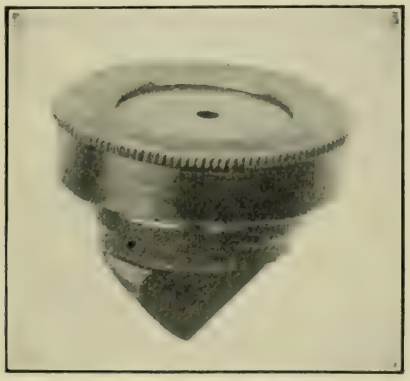

Fig. 177.—Angle disc nozzle which throws a cone-shaped spray; of larger capacity than the Vermorel. (*From U. S. D. A. Farmers' Bull.* 908.)

small aperture in the center of the thin disc that covers the outer end of the whorl chamber. The angle at which the liquid enters the chamber, the depth of the chamber, the size of the discharge aperture, and the pressure determine the fineness of the spray particles. The shallower the chamber, the smaller the particles, if the other factors are equal. The same effect is produced by increasing the angle at which the liquid

FIG. 178.—The Worthley solid-stream nozzle, with spreader attached at tip. (*From U. S. D. A. Dept. Bull.* 480.)

enters the chamber, or, up to a certain point, by increasing the pressure or decreasing the size of the discharge aperture. Increasing the pressure with the other factors equal will increase the fineness of the spray particles. The spray from this type of nozzle is thrown out in the form of a hollow cone, the size and shape of the cone also depending on the factors just mentioned. Enlarging the aperture increases the width of the cone and the amount of liquid discharged. Increasing the pressure has the same effect. In the earlier types of Vermorel nozzles, a disgorging pin was placed in the center of the chamber, the point of the pin being held so that it could be forced through the aperture to dislodge particles that had clogged the opening (see Fig. 176).

The disc nozzle as now constructed will, with proper adjustments, give a fine spray with enough driving power to cover the foliage. The larger disc nozzles, such as used on the spray gun, will deliver a large volume of liquid, enabling the operator to work rapidly. The fact that the spray is delivered in the form of a hollow cone has some disadvantages, but the fact that the nozzle is, or should be, moved continuously while the spray is being discharged should insure a thorough distribution. The disc nozzles and Vermorel nozzles are generally used for orchard spraying in clusters of from two to four attached to a Y-shaped extension on the end of the spray rod, or singly on 3- or 4-foot rods for garden work.

Solid-stream Spraying.—This method of spraying has been developed in the eastern section of the United States, where, because of the presence of the gypsy moth, elm leaf beetle, and other insects, it has become necessary to spray large street and park trees or good-sized tracts of woodland. To accomplish such work requires a nozzle that will throw a stream from 50 to 100 feet (Fig. 179), and give a thorough covering of the foliage at such heights. The nozzle now used for this work is called the "Worthley" (Fig. 178). With this nozzle the stream is forced at a high pressure through a smooth bronze tube inside of which is a fin-like device, used to overcome the rotary motion given to the water as it passed through the hose. This tube is from 40 to 60 inches in length, and at the end is attached a tip which reduces the size of the stream as it leaves the tube. The apertures in these tips vary from $\frac{1}{8}$ to

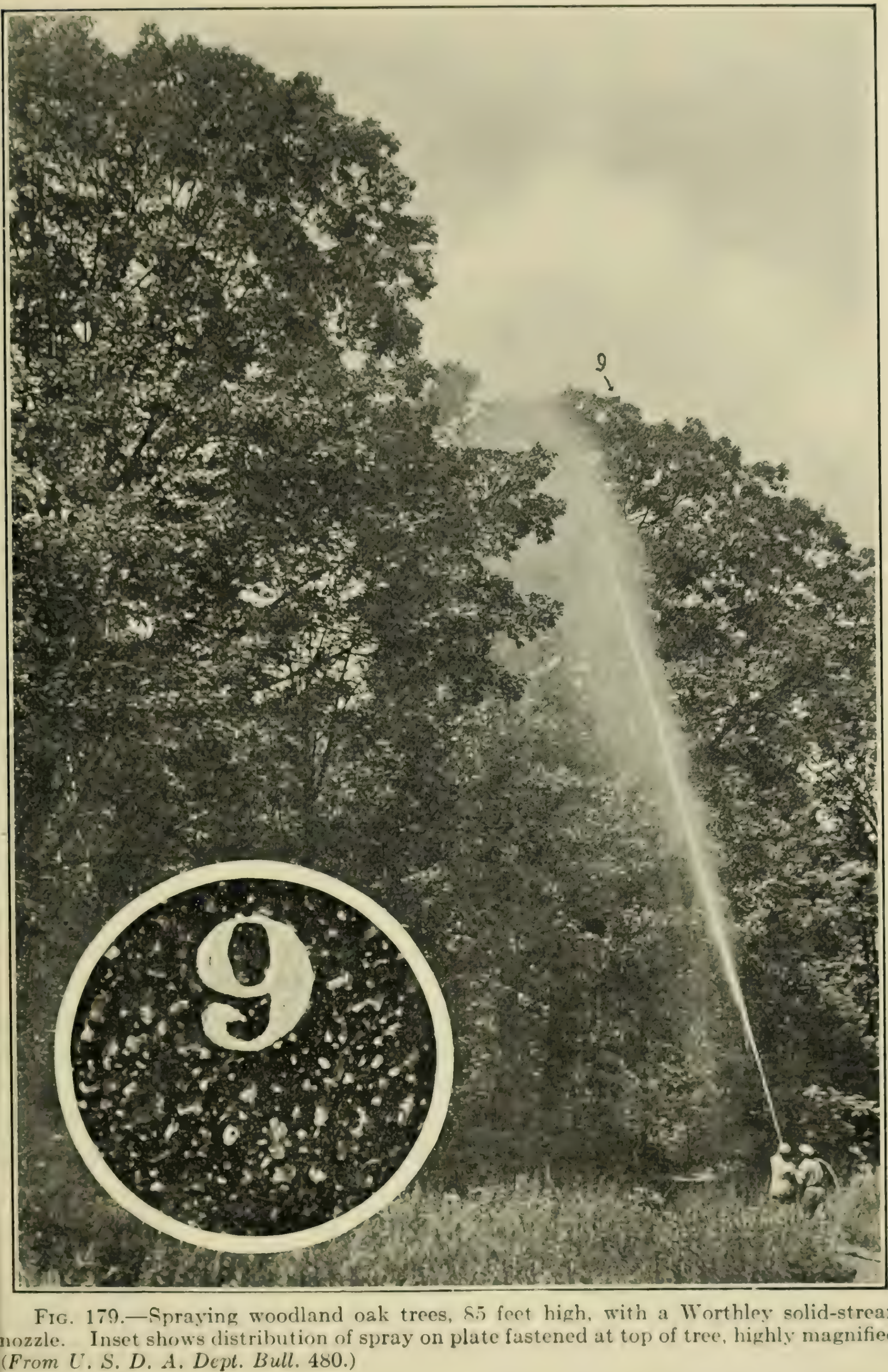

FIG. 179.—Spraying woodland oak trees, 85 feet high, with a Worthley solid-stream nozzle. Inset shows distribution of spray on plate fastened at top of tree, highly magnified. (*From U. S. D. A. Dept. Bull.* 480.)

$^5/_{16}$ inch, and discharge from 6 to 45 gallons per minute at 250 pounds' pressure. For spraying shrubs or low branches of trees, a curved brass strip, or spreader, is attached to the outside of the nozzle. When this is pushed out to a point where it comes in contact with the stream as it leaves the nozzle, the stream is broken up into a rather coarse mist. With the longer nozzles of this type, and a pressure of 300 pounds at the nozzle, it is possible to spray trees from 70 to 100 feet in height, and give a very thorough and uniform covering of the upper foliage. In the work in woodlands and large parks, it is often necessary to use long leads of hose, 1 to 1¼ inches in diameter and, at times ½ to 1 mile in length. Where such length of hose is used, a pump pressure of from 500 to 800 pounds is necessary to maintain a pressure of 250 pounds at the nozzle. For this type of spraying, an engine of 20 or more horsepower is needed. Most of these large sprayers are mounted on trucks with double transmission, so that the full power of the engine can be used for the pump when not moving, or can be used to drive both truck and pump when the truck is in motion[1] (see Fig. 173).

Spray Booms.—For the spraying of such crops as grapes, small fruits, nursery trees, and field crops in general, many special types of sprayers have been developed. These usually consist of an arrangement of nozzles of the disc type, attached to frames of metal called *booms*, in such a manner and in sufficient numbers to insure a thorough covering of the foliage, often on both the upper and under surfaces. With such sprayers, care should be taken that hose connections from the pump are adequate to supply each nozzle with the spray mixture; that the nozzles are readily detachable for cleaning; that the pump and motive power to drive it are large enough to maintain the pressure necessary to efficient operation; and that they will maintain the capacity rate of discharge of the nozzles. Where traction-driven outfits are operated, a triplex pump should be used. With such outfits, it is seldom possible to develop more than 150 pounds' pressure if 6 to 10 nozzles are attached to the boom. Because of the difficulty of maintaining even this low pressure, and because of the slipping of the wheels in soft ground, an engine-driven outfit is much more satisfactory. For such outfits, about 1 horsepower is necessary for each 4-gallons-per-minute discharge capacity of the nozzles.

Dusting Machinery

Although the original method of poisoning plants for insect control was by dusting, spraying has been much more extensively used during the past 50 years. Dusting is easier, lighter, pleasanter, and faster work than spraying. Two pounds of dust mixture have ordinarily as

[1] Solid Stream Spraying against the Gypsy and Brown-tail Moths in New England, *U. S. Dept, Agr., Dept. Bull.* 480, 1917.

much covering power as 10 gallons (80 pounds) of spray. The dust outfit is also much lighter than the spray rig and an equal force of men can, with a dust outfit, cover from several to many times the acreage possible by liquid applications.

There is probably not an orchardist, truck gardener, or grower of field crops, who would not, by preference, apply insecticides and fungicides in the dust form if he felt that he could secure as good, or very nearly as good, results with dusting as he could with spraying. Certain chewing insects have been fairly well controlled for many years by applications of dust to the leaves of the plants. Other chewing insects and sucking insects have not been controlled at all in this way. In most cases, it is desirable to make applications for the control of diseases

FIG. 180.—A useful shaker for applying dusts, made from a gallon tin pail and a wooden extension handle. The pail should have a tight-fitting lid. (*From Ill. Agr. Exp. Sta. Bull.* 249.)

and insects at the same time, and for this reason, a dust which would come into general use must be one that will contain a stomach poison, a contact insecticide, and a fungicide. Until such a satisfactory combination dust is discovered, general reliance for the protection of many crops will be placed upon liquid-spray mixtures.

A good duster, like a good sprayer, is one that will spread the insecticide—in this case in dry form—in such a manner as to give the most uniform coating possible to the plants to be treated. For the reason that spraying has in the past proved somewhat more effective than dusting, there has been a wider range of development in spraying machinery; and because of the difference between the machinery required for the application of a liquid and that for a dust, sprayers have always been, and will continue to be, somewhat more complicated than dusters. During the last 10 years, however, there has been a great advance in

the materials used for dusting and in the machinery with which these materials are applied.

The only dusters in use, up to about 1900, consisted of modified bellows, or small hand machines, from which the dust was discharged by the air blast created by a revolving fan. At present, there are many kinds and types of dusters on the market. These consist, in general, first, of small *hand dusters* adapted to small gardens, having a metal chamber with a plunger which is pulled back and forth by means of a handle, and which discharges a blast of air through a second chamber containing dust. Many different forms of these plunger dusters are

FIG. 181.—Dusting potatoes with a hand-blower duster suitable for garden work. The figure shows the use of the Y attachment to cover two rows. (*From Niagara Sprayer Co.*)

made; in fact, there are almost as many different kinds as there are companies making them. Some of them are well constructed, and, with reasonable care, will last for several years. Next in size are the *blower dusters* (Fig. 181), which consist of an enclosed fan rotated by a hand crank which sends a continuous blast of air through a small chamber into which the dust is fed from a hopper. Most of this type of dusters do, and all of them should, contain some sort of an attachment for keeping the dust stirred in the hopper, and for providing an even feed through the discharge chamber. These dusters can be used for a considerably larger area of truck crops than can be covered by the same sized sprayer. In fact, 1, 2, or even 5 acres may be protected with a good blower type of hand duster. Dusting several acres with a hand duster is tiresome work, and if several applications of dust have to be made to such acreage, a larger machine should be used.

Another type of duster of about the same size is the *bellows duster*, With this type, the air is forced through the discharge chamber by the extension and compression of a bellows attached to the back of the duster. This gives a discharge of the dust in puffs instead of a continuous stream as with the blower type. The bellows-duster, or "puff" duster as it is sometimes called, is well adapted to hill crops, but is not suitable for row crops. It is also fairly satisfactory to use on small trees and shrubbery.

There are a number of dusters which have been developed for field-crop dusting, in which the fan is geared to the wheel or wheels on which the duster runs. Such dusters are called *traction dusters*. A type which is quite generally used in the South for small acreages of cotton,

FIG. 182.—Dusting potatoes with a two-horse, field-crop, traction duster, with discharge pipes arranged to cover four rows. (*From Niagara Sprayer Co.*)

has much the same appearance, and is built in much the same way, as a one-horse cultivator. The operator guides the machine by two handles, which extend back from the frame. The discharge pipes extend back parallel with the handles but are slightly longer, and can be adjusted to deliver the dust at an angle on each side of the operator. Such dusters will do fairly well for 10 or 15 acres of field crops. They are rather disagreeable to use, because of the fact that the operator is exposed to the dust most of the time while the work is being done.

There are a number of larger-type traction dusters now being developed for work on field crops; which consist, in general, of a two-wheeled frame with some arrangement for driving the fan from the wheels. These machines will develop a fair amount of power, and are capable of turning a 12- to 16-inch fan at 2,500 to 3,000 revolutions per minute. The hopper of such a machine holds from 50 to 100 pounds of dust, or enough to cover several acres. Such machines are drawn by at least two mules,

and if properly constructed, will do very effective work. There are various modifications of the discharge from these machines depending on the type of crop to be treated (Figs. 182 and 183). Some of these large dusters (Fig. 182) adapted for field crops have four main discharge pipes, each pipe branching again to permit the use of eight nozzles, and so making it possible to apply the dust to each side of the four rows covered by the machine on each trip through the field. The greatest difficulty with these machines is to get an even distribution of air into all the pipes. With certain types of field crops, particularly those that are broadcasted, it has not been possible to secure an even distribution with the branched pipes. Some machines are now made with a single discharge pipe which conveys the dust into a triangular, trough-shaped

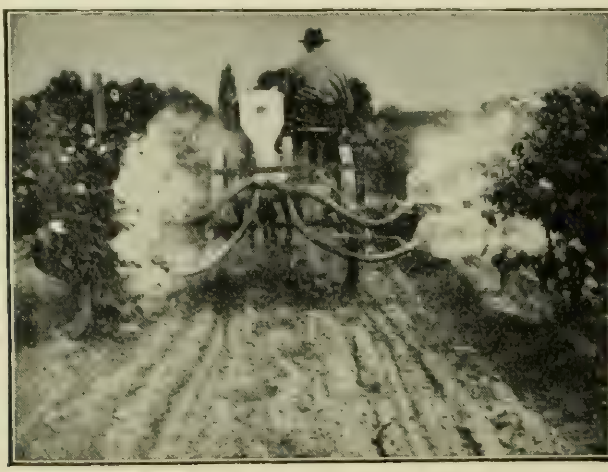

FIG. 183.—Dusting grapes with a vineyard traction duster. (*From Niagara Sprayer Co.*)

boom. This type of discharge boom has been particularly developed for work on the pea aphid, and has proved much more satisfactory than the numerous discharge pipes. Owing to the fact that the speed of the machines will vary with the rate at which they are drawn through the field, and that the wheels may slip in soft ground, it is always difficult to maintain an even discharge from traction-type dusters.

Most of the dusters now in use for orchard and field-crop work, are engine-driven. With a 4- to 6-horsepower engine operating the fan of such a duster, it is possible to get a very uniform distribution over the plants treated. The orchard dusters (Fig. 184) are built on the same principle as the traction, field-crop dusters, but instead of having many discharge pipes, the dust is blown out over the trees from one large flexible pipe. The rate of discharge of the dust is controlled by the size of the opening from the hopper into the discharge chamber. This rate can be maintained more uniformly than the discharge of liquid from a sprayer. In the larger-type dusters there is a tendency at present to have the hopper discharge directly on to the fan instead of into a

separate chamber. There is some advantage in this method of discharge; the dust is given a somewhat higher velocity, and the force of discharge can be more easily regulated by increasing or diminishing the speed of the fan.

Another type of duster now put on the market by some of the large manufacturers has a mixing attachment in the hopper by which it is possible to mix the ingredients of the dust immediately before it is applied. This is of importance where volatile substances, such as nicotine, are to be used in the dust, as it insures an absolutely fresh material. There are many other styles of dusters made to meet the

FIG. 184.—Dusting apple trees with an engine-driven, orchard duster. (*From Niagara Sprayer Co.*)

particular needs of certain crops, such as vineyard dusters, nursery dusters, corn dusters, cotton dusters, and dusters for large shade trees. The shade-tree dusters, however, have not as yet been developed to a point where they can be said to be a success.

With dusting machines, as with spraying machines, one should carefully study the problem before selecting a machine. Find out first the rate per tree or per acre at which the dust should be applied for the control of the particular insects to be combated, and get a machine capable of applying dust somewhat in excess of this rate. For extensive work, a power-driven machine is highly desirable. The machine should have provision in the hopper for keeping the dust stirred so that it will not cake and clog, and some method of insuring a positive feed at a

uniform rate into the discharge chamber. With some of the volatile dusts, particularly with nicotine where it is used for rather resistant insects, it has been necessary to attach a trailer behind the duster. This trailer consists of a piece of canvas attached across the back of the duster, and dragging behind for a distance of from 10, to as much as 40 feet (Fig. 300). The purpose of these trailers is to confine the fumes given off from the dust and expose the insects to them for a longer period.

Airplane Dusting

One of the most recent developments has been that of airplane dusting (Fig. 185). The first use of the airplane in the control of insects

Fig. 185.—Dusting peaches with an airplane; the cloud of dust discharged from the plane at a height of about 15 feet above the tree tops. (*From Ill. State Nat. His. Sur.*)

was made in Ohio, in 1921, against the catalpa sphinx. By this method, large quantities of the dust are discharged from hoppers built into the airplanes, which fly over the fields or woodlands. The dust so discharged is distributed by the air from the propeller of the plane and settles in a very uniform manner over the plants or trees beneath. In airplane dusting, planes specially designed for this work fly at speeds of 70 to 120 miles an hour and at heights of 10 to 35 feet from the ground. Swaths from 100 to 200 feet wide are dusted, and the plants are covered at the rate of 4 to 12 acres a minute of actual dusting time or 200 to 500 acres an hour by a single plane.

The airplane has been successfully used in the control of the cotton-boll weevil, gypsy moth, sugar-cane borer, and spruce budworm, in

dusting peaches for insects and plant diseases, in destroying mosquito larvæ in impenetrable swamps, and for certain shade- and forest-tree insects in Ohio and Canada. It has also been of great assistance in scouting for insect outbreaks in remote areas of forest lands. Certain commercial companies have aided greatly in the perfection of planes and in placing this work on a practical basis. Where large areas of crops sufficiently concentrated to justify the employment of a plane occur, commercial companies will contract to do dusting at prices below the cost of ground dusting. The work is, in general, quite as well done, requiring little, if any, more materials and with no more danger to surrounding fields and homesteads than results from ground dusting. The speed with which the application can be made is a point of very great advantage in the control of many pests.

Another point in regard to dusting which has recently come to the knowledge of investigators is the fact that the dust on leaving the machine is given a certain electrical charge. This charge may be the same as that held by the leaf surfaces over which it is blown; if this is the case, the dust is repelled; as objects with the same electrical charge are mutually repellent. If the charge of the dust particles is different from that of the leaf, they will be attracted, and stick to the leaf surface. There is apparently a difference in the charge given to dusts of different kinds by passage through a duster. Investigational work is now being carried on along this line which may result in a great increase in dusting efficiency.

CHAPTER XI

INSECTS INJURIOUS TO CORN

Corn is the most important farm crop in the United States, having an average value for the past 10 years of more than $2,000,000,000. Insects attack every part of the plant throughout its growth, and year after year destroy more than 5 per cent of the crop. The portion of this one crop lost because of insect damage would, at current market prices, be sufficient to support 20 large universities, or build 2,000 miles of modern, hard-surfaced road each year. Control is difficult, on the whole, because of the extensive areas and the relatively low value of the crop per acre, which make it necessary to depend mostly upon farm practices and other indirect control measures. Nevertheless, many of the insect pests of corn can be very effectively controlled if the best known remedies are properly applied.

FIELD KEY FOR IDENTIFICATION OF INSECTS INJURING CORN

A. Insects attacking the seed under ground; plants often fail to come up:

1. Seed fails to sprout or makes a weak sprout. Dirty, yellowish-white, legless maggots about ¼ inch long, blunt at the posterior end, tapering sharply to the head, may be found burrowing in the kernels of corn in the ground, or in the earth around the kernels. *Seed-corn maggot*, p. 300.

2. Seed fails to sprout or plantlet is weak. White, very slender worms or larvæ, slightly over ¼ inch long when full-grown, with yellowish-brown head and six short legs burrowing in the kernels and sometimes in the sprout. *Pale-striped flea beetle*, p. 302.

3. Seed fails to sprout, or plant dies when small. Slick, shining, brown to reddish-brown, smooth, hard, six-legged worms, 1 to 1½ inches long, boring through the kernels and young plants. *Wireworms*, p. 303.

4. Seed does not sprout. Brownish or blackish-brown beetles, about ⅓ inch in length, feeding in kernels of corn in the ground. *Corn-seed beetles:* the darker, brown-striped one, *Agonoderus pallipes;* the uniform chestnut-brown one, *Clivina impressifrons*, p. 305.

5. Seed produces a weak sickly sprout. Starchy parts of kernel eaten out and scattered through the ground by very small, orange-colored ants. *Thief ant* or *fire ant*, p. 306.

B. Insects attacking the roots:

1. Plantlet weak, reddish to yellowish in color. Small brown ants tunneling the ground along the corn roots, and sometimes feeding on the starchy parts of the kernel. Carrying about and caring for small bluish-green aphids, on the corn roots. *Corn field ant*, p. 315.

2. Plants weak, leaves reddish or yellowish. Bluish-green plant lice or aphids, about the size of pin heads, sucking the sap from the roots; always attended by ants. *Corn root aphid*, p. 314.

3. Plant makes slow growth, dies, and sometimes falls over. Often distinct areas in field showing injury. Roots eaten off clean, not tunneled, by white, curved-bodied, six-legged grubs, from ½ to over 1 inch long, with large brown heads and distinct jaws. *White grubs*, p. 306.

4. Corn plants following clover sod are stunted, seldom reaching a height of over 8 or 10 inches. Plants wilt during hot, dry days. Small, short, white, fat-bodied grubs, not over ⅛ inch long with light-brown heads, gnaw on the roots. Grubs hold body in a curved position. Cease feeding during June. *Grape colaspis*, p. 313.

5. Corn on land which has been in this crop for one or more years falls over about the time the tassels appear, frequently after a rain has softened the ground. Roots eaten off or containing many, small, brown tunnels in which will sometimes be found slender, whitish worms about ½ inch long with distinct brown heads and six short legs. *Northern corn rootworm*, p. 310.

6. Corn falls as in *B*, 5, but the injury is not confined to old corn ground. Underground parts of stalk as well as roots show tunnels. Slender yellowish-white worms having much the same appearance as those described under *B*, 5, but slightly larger and more robust. *Southern corn rootworm*, p. 311.

7. Corn wilts and dies when from 1 to 4 feet high. Sometimes falls over. Injury most common to corn in old sod ground. Large, fleshy, legless, whitish grubs from ½ to 2 inches long, with the body enlarged just behind the head, not curved, and with strong brown jaws. *Corn prionus;* see *Eighteenth Rept. State Entomol., Ill.* p. 128, 1891–1892.

C. Insects attacking the leaves and stalk above ground:

1. Corn leaves with irregular patches eaten out, giving plant a ragged appearance. Often the plant is entirely stripped of leaves. Dark-green worms up to 2 inches in length with light stripes on the sides and down the middle of the back, feed usually at night and hide under clods or in the heart of the plant during the day. Skin when seen through a lens appears smooth. Worms often moving into the corn in large numbers from nearby fields of grass or small grains. *Army worm*, p. 318.

2. Injury similar to *C*, 1, by worms which often crawl in great numbers from field to field. Distinguished from true army worms, under a lens, by the greater length of the hairs and their more prominent black bases on the smooth skin, by the prominent λ on the front of the head and by the somewhat different striping. *Fall army worm*, p. 435.

3. Corn plants under 1 foot in height cut off, mostly at night, below, at, or slightly above the surface of the ground. Fat, well-fed, smooth-appearing worms with six slender legs and five pairs of prolegs, of varying sizes up to 2 inches in length and of several shades and markings, hide under the ground or clods near the injured plants. Many kinds curl the body when disturbed. *Cutworms*, p. 321.

4. Young corn plants up to 8 or 12 inches in height eaten into or cut off near the surface of the ground. A loose silken web containing many bits of dirt, leading to a short, silk-lined tunnel in the ground. Short, dirty-colored, brown-spotted, coarse-haired worms, from ¼ to ½ inch long, usually hidden in these silken tunnels. *Sod webworms*, p. 324.

5. Leaves of young corn with green portion eaten out, presenting a whitened bleached appearance. Plant growth is retarded and leaves wilt and hang limp. Leaves covered with dull or shining black or greenish-black, small, jumping beetles from a little smaller than a pinhead, to several times as large. *Flea beetles*, p. 325.

6. Leaves of plant ragged and sometimes entirely eaten off. Tips of ears gnawed. Fields presenting a ragged appearance, bare stalks standing without leaves. *Grasshoppers*, p. 327.

7. Flesh-colored caterpillars from ½ to 1 inch long, with inconspicuous, small, round, brown spots scattered over the body, boring in all parts of the stalk, shank of

ear and ear. Tassels frequently broken off from injury at the base. Many caterpillars often found in one stalk. *European corn borer*, p. 333.

8. Corn stalks, especially those around margins of fields, bored during June and July, by very active, dark-brown worms or caterpillars, with two white stripes on each side, which are broken for about one-fourth their length near the middle of the body, and a continuous white stripe running down the center of the back. The caterpillars reach a length of 1½ inches. *Common stalk borer*, p. 337.

9. Stalks bored by slender, greenish worms with longitudinal brownish markings, about ¾ inch long when full-grown. Stalks become much distorted and curled by the early-season injury. Most abundant in the south. *Lesser corn-stalk borer*, p. 338.

10. Stalks bored throughout their length by white worms, up to 1 inch in length, conspicuously marked with rounded brown spots; not common in the North. *Larger corn-stalk borer*, p. 339.

11. Unfolding corn leaves with rows of holes running across the leaves. Cavities eaten in the sides of the plant by black or clay-colored beetles with long slender snouts nearly one-third the length of the body. Beetles from ¼ to 1 inch in length. Injury most severe on newly drained or sod land. *Grass* or *rush billbugs*, p. 340.

12. Injury same as C, 11, but most severe on old corn ground. In addition to the injury by the beetles, white, legless, fat-bodied grubs with light-brown heads, burrow inside the stalk. *Maize* or *corn billbug*, p. 342.

13. Leaves of the corn plant covered with masses of bluish-green plant lice or aphids, most abundant in the curl of the plant and on the developing tassel. Infested plants scattered over the field. *Corn leaf aphid*, p. 344.

14. Corn wilting, drying out, and falling down, on the side of the field next to small grains. Small, active, reddish or black-and-white sucking bugs clustered behind the lower leaves and over the entire lower part of the stalk; when crushed, giving off a vile odor. Fields invaded by hordes of these insects at the time of small-grain harvest. *Chinch bug*, p. 344.

D. Insects attacking the ear:

1. Silk fouled with moist masses of excreta, many of the silks cut off; kernels at the tip of the ear eaten by large worms varying in color from very dark green to light green. Bodies of the worms sparsely haired, skin rough-appearing under a lens. Worms nearly 1¾ inches long when full-grown and usually only one to the ear. Occasionally the worms enter at the butt of the ear, but usually at the tip. They do not tunnel into the cob. *Corn earworm*, p. 350.

2. The ear, its cob and shank tunneled throughout and many of the kernels and the silk eaten by flesh-colored, inconspicuously spotted caterpillars up to 1 inch long. Many worms often found in one ear. Husks perforated with small holes with exuding frass. *European corn borer*, pp. 333 and 353.

3. Clusters of dark-green beetles about ½ inch long by ¼ inch across, feeding on silks and husks, especially at the tip of the ear. Wing covers of the beetles shining. Four prominent white spots on the tip of the abdomen, which projects from under the greenish-brown wing covers. *Japanese beetle*, p. 353.

General References.—Eighteenth and *Twenty-third Repts., State Entomol., Ill.*, 1891–1892 and 1905.

Seed-corn Maggot[1]

Importance and Type of Injury.—The seed infested by the seed-corn maggot usually fails to sprout, or, if it does sprout, the plant is weak and sickly. The pale-to-dirty-colored, yellowish-white maggots (Fig. 186)

[1] *Hylemyia cilicrura* Rondani, Order Diptera, Family Anthomyiidæ.

will be found burrowing in the seed. Injury is usually most severe in wet, cold seasons and on land rich in organic matter.

Plants Attacked.—Corn, beans, peas, cabbage, turnip, beets, radish, seed potatoes, and several others.

Distribution.—This species is widely distributed in Europe. It was first found in this country in 1856, in New York. It has now spread over nearly the entire United States and southern Canada.

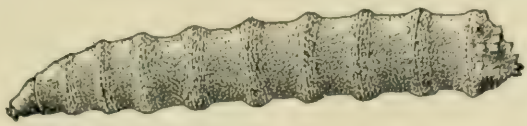

Fig. 186.—Larva of the seed-corn maggot, *Hylemyia cilicrura Rondani*, side view, eight times natural size. (*From Ill. State Nat. Hist. Sur.*)

Life History, Appearance, and Habits.—The winter is probably passed in the soil of infested fields in the maggot stage inside of a dark-brown capsule-like puparium about 1/5 inch long. The flies (Fig. 187), which are grayish-brown in color and about 1/5 inch long, are abroad in the

Fig. 187.—Adult of the seed-corn maggot, *Hylemyia cilicrura* Rondani, eight times natural size. (*From Ill. State Nat. Hist. Sur.*)

fields early in May in the latitude of central Illinois. They deposit their eggs in the soil where there is an abundance of decaying vegetable matter or on the seed or plantlet. The maggots burrow in the seed, often destroying the germ. When full-grown, they are of a yellowish-white color, about 1/4 inch long, sharply pointed at the head end, legless, and very tough-skinned. They change to the pupal stage inside the brown puparium in the soil, and in from 12 to 15 days emerge as adults.

The number of generations is not known, but there are probably from three to five each season throughout the corn belt.

Control Measures.—No effective practical control is known. Planting in a well-prepared seedbed, sufficiently late to get a quick germination of the seed, is probably the best means of preventing injury. Land that is heavily manured, or where a cover crop is turned under, should be plowed early in the fall if possible, so it will be less attractive to the egg-laying flies, the following spring.

References.—*U. S. Dept. Agr., Division Entomology, Bull.* 33, n. s., pp. 84–92, 1902; *N. Y. (Cornell) Agr. Exp. Sta. Memoir* 55, 1922.

Pale-striped Flea Beetle[1]

Importance and Type of Injury.—Corn seed attacked by the larva of this flea beetle often fails to sprout or produces a pale, weak plant. If the seed is examined, it will be found to be injured by very slender white worms, a little over ¼ inch long, with light-brown heads, six very short

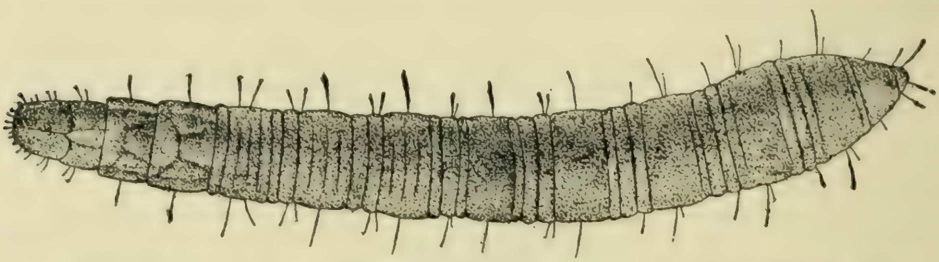

Fig. 188.—Larva of the pale-striped flea beetle, *Systena tæniata blanda* (Melsheimer), dorsal view, about 15 times natural size. (*From Ill. State Nat. Hist. Sur.*)

legs, and the body tapering slightly towards the head (Fig. 188). Injury is usually most serious during periods of cool weather, which retards the germination of the seed after planting.

Plants Attacked.—The adults of this species have been found feeding on a great variety of cultivated plants and weeds, including watermelon, pumpkin, pea, bean, eggplant, potato, sweet potato, pigweed, lamb's quarters, purslane, ragweed, cocklebur, wild sunflower, alfalfa, and many others. Lamb's quarters and shepherd's purse seem to be preferred by the larvæ.

Distribution.—This species is distributed generally over temperate North America. It is probably a native species.

Life History, Appearance, and Habits.—The winter stage is not known, but the insect probably hibernates as an adult or pupa. The adult beetles (Fig. 189) are about ⅙ inch in length, with the margins of each wing cover pale brown to nearly black and with a broad, median, white stripe. The legs are dull red. The beetles appear by May 1 in the southern part of the corn belt. Larvæ will often be found on the

[1] *Systena tæniata blanda* (Melsheimer), Order Coleoptera, Family Chrysomelidæ.

earliest-planted corn seed. The larvæ bore through the kernel, often destroying the germ and thus preventing growth. The larval period has not been definitely worked out, but is, judging from the time of appearance of the first adults in the summer, about 1 month. There is probably one complete generation a year in the latitude of central Illinois.

Control Measures.—The damage by this insect has been most severe in fields which were weedy the previous season. Keeping down weeds will help in preventing damage the next season. Early plowing and late planting of corn fields is also of value. These measures will starve out many of the larvæ in the soil before the corn is planted. Probably the most effective measure of control is planting good seed sufficiently late so that the corn will make a quick, strong growth, and the seed will not lie in the soil long enough to be seriously damaged by the larvæ.

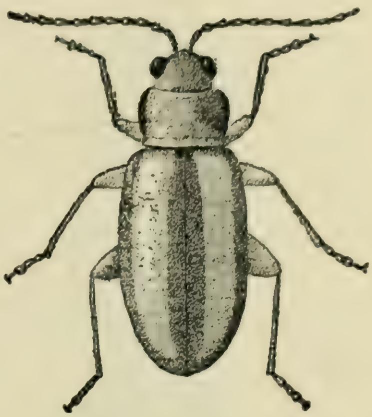

FIG. 189.—Adult of the pale-striped flea beetle, *Systena tœniata blanda* (Melsheimer), about ten times natural size. (*From Ill. State Nat. Hist. Sur.*)

References.—*Twenty-third Rept. State Entomol. Ill.*, p. 107, 1905; *N. Y.* (*Cornell*) *Agr. Exp. Sta. Memoir* 55, 1922.

WIREWORMS[1]

Importance and Type of Injury.—Corn that is attacked by wireworms soon after the seed is planted seldom germinates, as the holes eaten by the worms nearly destroy the kernel. The seeds may germinate and the young plant be attacked by the worm, which often bores through the

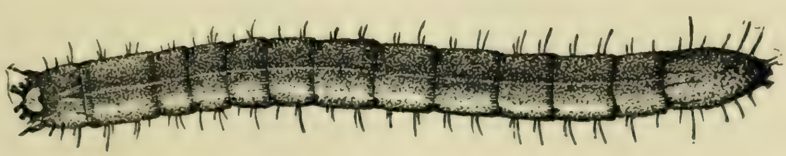

FIG. 190.—Larva of the corn wireworm, *Melanotus cribulosus* (Leconte), about 3 times natural size. (*From Ill. State Nat. Hist. Sur.*)

underground part of the stalk and causes the plantlet to die. The wireworm larvæ (Fig. 190) are usually hard, dark-brown, smooth, wire-like worms, varying from ½ to 1½ inches in length when grown. Some species are soft, and white or yellowish in color. Their injuries are usually most severe to corn planted on sod ground, or the second year from sod.

Plants Attacked.—Wireworms attack nearly all crops belonging to the grass family and many other plants; including corn, wheat, clovers, beans, potatoes, and beets.

[1] Many species of the Order Coleoptera, Family Elateridæ.

Distribution.—Throughout North America, and most of the world.

Life History, Appearance, and Habits.—There are many different species of wireworms that attack our cultivated crops, including corn. The winter is passed mainly in the larval and adult stages in the ground. In the early spring, the adults (Fig. 191) become active and fly about, some species being strongly attracted to sweets; and these can be taken in large numbers by placing a few drops of syrup on the tops of fence posts or other exposed places out-of-doors. They are "hard-shelled," usually brownish, grayish, or nearly black in color, somewhat elongated, with the body tapering more or less towards each end. The head and thorax fit closely against the wing covers, which protect the back of the abdomen. The joint just in front of the wing covers is loose and flexible, and when the beetles are placed or fall on their backs, they flip the middle part of the body against the ground in such a manner as to throw themselves several inches into the air. The chances of their alighting on their feet seem to be about fifty-fifty; but they will generally keep trying until they come down right side up, when they make use of their legs to escape. This habit has afforded amusement to most country boys and girls, and has given the insects such names as click-beetles, snapping beetles, and skip-jacks. The females of the species that are most injurious to corn, lay their eggs mainly in the soil around the roots of grasses. The larvæ hatching from these eggs spend from 2 to 6 years in the soil feeding on the roots of grasses and other plants. The last segment of the larva is usually characteristically ornamented and serves to distinguish different species during this stage (Fig. 192). Most species change to the pupa, and later to the adult stage, in cells in the ground, during the late summer or fall of the year in which they become full-grown. The adults, which are commonly about ½ inch long, remain in the soil until the following spring.

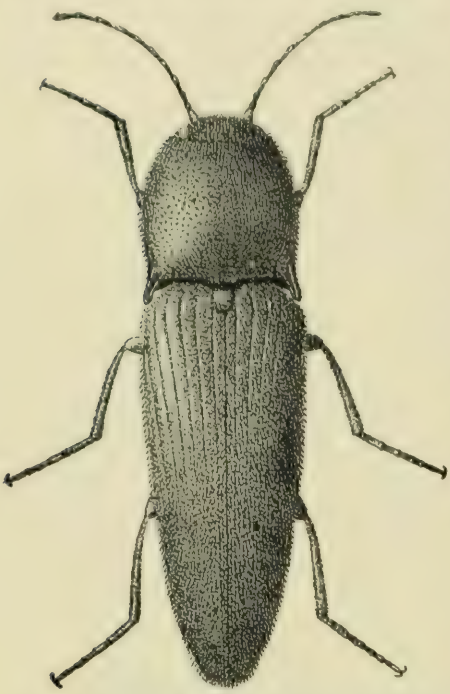

FIG. 191.—A click beetle, adult of the wireworm, *Melanotus fissilis* (Say), about 5 times natural size. (*From Ill. State Nat. Hist. Sur.*)

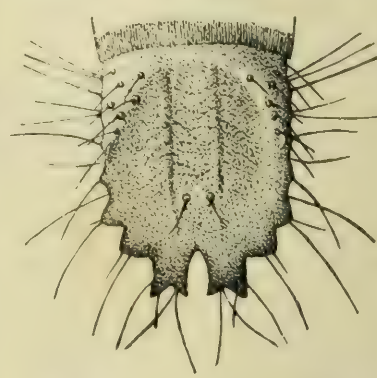

FIG. 192.—Terminal segment of larva of a wireworm, *Drasterius elegans* Fabricius, much enlarged. (*From Ill. State Nat. Hist. Sur.*)

Control Measures. There are no satisfactory control measures known that can be applied to infested fields to rid them of wireworms. Late summer or fall plowing is of some value in killing the pupæ and adults by breaking up their cells in the soil. Rotations that will permit the growing of small grains or legumes on second-year sod also help in lessening the damage by these insects, as the percentage of such plants killed by them is not large enough seriously to affect the yield of these crops. Certain species of wireworms are abundant only in poorly drained soils. The proper draining of such soils will entirely prevent damage by these species. Extensive experiments carried on at a number of different points to develop a treatment for seed corn that would prevent wireworm injury have failed in showing any practical method by which this can be done. (See also p. 432.)

References.—U. S. Dept. Agr. Farmers' Bulls. 725, 1916 and 733, 1916; *Dom. Canada, Dept. Agr. Pamphlet* 33, n. s., 1923.

Corn-seed Beetles[1,2]

Importance and Type of Injury.—Sometimes when corn seed fails to sprout, an examination of the kernels will show dark-brown, striped,[1] or nearly chestnut-brown[2] beetles about 1/4 to 1/3 inch long eating out the contents (Fig. 193). This injury seldom occurs except where seed of low vitality has been used, or when cold weather has greatly delayed germination.

Fig. 193.—Adult of the corn-seed beetle, *Agonoderus pallipes* Fabricius, and injury to kernel. Line indicates natural size. (*From Ill. State Nat. Hist. Sur.*)

Plants Attacked.—These two beetles are mainly feeders on insects, or insect remains, and only rarely attack seeds.

Distribution.—The greater part of the United States and Canada.

Life History, Appearance, and Habits.—The life history of these beetles is not known. They probably pass the winter in the adult stage, as they are abroad very early in the spring. They may often be seen in large numbers at electric lights.

[1] *Agonoderus pallipes* Fabricius, Order Coleoptera, Family Carabidæ.

[2] *Clivina impressifrons* Leconte, Order Coleoptera, Family Carabidæ.

Control Measures. Planting sufficiently late to insure quick germination of the corn seed, and using seed of good vitality is the best method of overcoming the damage caused by these insects.

Reference.—Eighteenth Rept. State Entomol. Ill., p. 11, 1891–1892.

Thief Ant[1]

Importance and Type of Injury.—An examination of a corn kernel that has failed to sprout, or that has produced a weak plant, will sometimes show many little starch grains scattered through the soil about the kernels and the entire inside of the seed hollowed out. Frequently very small, orange-red ants will be found actively working in the kernels (Fig. 194).

Plants Attacked.—Seeds of corn, sorghum, millet, and probably other plants.

Distribution.—General throughout North America.

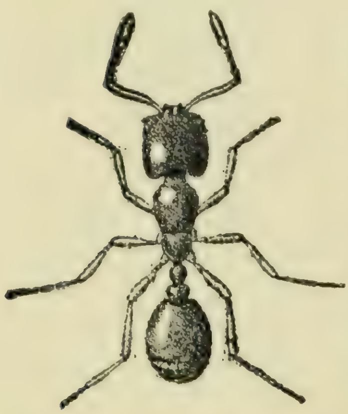

Fig. 194.—Worker of the thief ant, *Solenopsis molesta* Say, about twenty-five times natural size. (*From Ill. State Nat. Hist. Sur.*)

Life History, Appearance, and Habits.—The winter is passed in all stages of development in nests in the soil. These nests are often made in the walls of the nests of larger species of ants. The workers of this small species obtain a part of their food by preying upon the helpless larvæ and pupæ of the larger species. This has given them their common name of thief ant. The workers of this species are about $\frac{1}{20}$ inch long, of an orange-yellow color. The males are slightly larger and black. The females, or queens, are brown and very much larger, being about $\frac{1}{4}$ inch long. Certain other species of ants rarely cause similar injury.

Control Measures.—The seed treatments that have been used for preventing injuries by these ants have not proved of much value. The best method of preventing their injuries is thorough cultivation of the soil before planting. This will break up their nests and scatter the young, and so greatly reduce their numbers in the field. Surface planting aids in control.

Reference.—Ill. Agr. Exp. Sta. Bull., 44, p. 214, 1896.

White Grubs or June Beetles[2]

Importance and Type of Injury.—When fields infested with white grubs are planted to corn, the corn usually comes up but the plants cease growing after reaching a height of from 8 inches to 2 feet. The corn will show a patchy growth with varying sized areas in the field where the plants are dead or dying. If the injured plants are pulled up, the roots will be found to have been eaten off, and from one to as many as 200, white, curved-bodied grubs, from $\frac{1}{2}$ to over 1 inch in length, will be found in the soil about the roots. The grubs (Fig. 195, *lower figure*) are white with brown heads and six prominent legs. The hind part of the body is smooth and shiny, with dark body contents showing through the skin. Injury is usually most severe to crops following sod.

[1] *Solenopsis molesta* Say, Order Hymenoptera, Family Formicidæ.

[2] *Phyllophaga* or *Lachnosterna* spp., Order Coleoptera, Family Scarabæidæ.

Plants Attacked.—All grasses and grain crops; potatoes, beans, strawberries and nearly all cultivated crops.

Distribution.—World-wide.

Life History, Appearance, and Habits.—The winter is passed in the soil in both the larval and adult stages. In the spring after the trees

FIG. 195.—Life stages of a white grub, *Phyllophaga rugosa* (Melsheimer). Above, pupa; at left, egg; at center, adult; below, larva. (*From Ill. State Nat. Hist. Sur.*)

have put forth leaves, the adults (Fig. 195, *center*) become active, fly about during the night, and feed on the foliage of trees and the leaves of some other plants. They leave the soil just at dusk and remain on the trees during the night, mating and feeding. At the first streaks of dawn, they

return to the soil, where the females lay their pearly-white eggs (Fig. 195, *left*) from one to several inches below the surface. While the beetles may be moving at dusk from the soil to the trees for an hour or more, the return to the soil at dawn takes place very rapidly. It frequently will not be over 10 minutes from the time the first beetle leaves the trees until they have all disappeared. The eggs are generally laid in grass lands, or patches of grassy weeds in cultivated fields. They hatch in 2 or 3 weeks, and the young grubs feed on the roots and underground parts of plants until early fall, when they are about ½ inch long. They then work their way down in the soil usually below the frost line, and have been taken 5 feet below the surface.

As the soil warms in the spring, they work upward and, by the time plant growth is well started, they are feeding a few inches below the surface. Feeding continues throughout the season, and on the approach of cold weather, they again go deep into the soil, where the second winter is passed, the grubs then being about 1 inch long. The third season they come up near the surface of the ground and feed until late spring or early summer, and then change to the pupal stage (Fig. 195, *upper figure*) in cells in the earth about 6 or 8 inches below the surface. During the latter part of the summer, they change to the adult beetle, but do not leave the soil until the following spring. There may be some movement of the beetles downward to below the line of severe freezing. The over-wintering population of white grubs, therefore, consists of adults that have not yet taken flight from the soil and of larvæ usually of two distinct sizes, the smaller about 9 months, and the larger about 1 year and 9 months old.

The adults are the well-known, brown, or brownish-black June beetles, May beetles, or daw bugs. A very large number of species are known. They vary somewhat in their life history, some completing their growth in 1 year, while others require as much as 4 years. The 3-year life cycle is by far the most common. There are several other closely related beetles that attack corn, the grubs differing somewhat in structure but having the same general appearance. There are also a number of grubs, very similar in appearance, which occur in the soil and manure, but which eat only decaying vegetable matter, and do not feed on the living roots of plants. These lack the double row of spines on the under side of the last body segment which is characteristic of the true white grubs.

Control Measures.—Land heavily infested by white grubs should not be planted to corn, potatoes, strawberries, or other seriously injured crops. Legumes, or small grains, will be much less severely injured. Early fall plowing will be of some value in killing the grubs if done before they have worked their way below the plow line. This kills the grubs by crushing them in the soil and by exposing them to birds.

One of the best ways of cleaning grubs out of fields is to pasture the land with hogs. This may best be done during the late summer and early fall. Where unringed hogs are allowed to run on heavily infested land, they will nearly free it of grubs. If this is done during the first year of the grubs' life, most of the damage by these insects may be prevented. Care must be taken in pasturing hogs on grub-infested land, as the white grub is the intermediate host of the giant thorn-headed worm, one of the intestinal parasites of hogs. Hogs that are to be marketed within a few months can be used without danger of injury, but breeding stock should not be used if hogs have had the run of the same land within the past 3 years.

FIG. 196.—A badly injured pasture sod; the blue-grass roots have been entirely eaten off by white grubs, permitting the rolling back of the sod like a carpet, to expose the grubs. (*From Ill. State Nat. Hist. Sur.*)

While white grubs are troublesome every year, the most severe injury occurs in regular 3-year cycles. These years of severe damage correspond to the second year in the development of the main brood of white grubs. This will be the year *after* that in which heavy flights of beetles occur. Throughout the eastern part of the United States, the years of most severe damage, as shown by Davis, will be 1930, 1933, 1936, and each third year thereafter. During these years, or any year following a heavy flight of May beetles, one should avoid planting corn on sod land and other land that has been covered with a grassy growth during the time of the beetle flight.

The grass crops (Fig. 196) are much more severely injured by white grubs than are legumes—soybeans being perhaps the least damaged of

any of our field crops. The beetles will not, as a rule, lay their eggs in fields of clover or alfalfa, but will sometimes do so when there is a considerable growth of grass in such fields. Corn planted on clover or alfalfa sod following years of heavy beetle flights will usually escape injury. Fields that were in clean-cultivated row crops during the heavy beetle flights, can usually be safely planted to corn the following spring.

The white grubs in the soil are attacked by several insect parasites, especially certain wasps that often become sufficiently abundant to greatly reduce their numbers. Birds, especially crows and blackbirds, pick many of the grubs out of the soil of grass lands and blackbirds will often follow the plow in infested fields picking up the grubs as they are turned out in the furrow.

References.—Ill. Agr. Exp. Sta. Bulls. 116, 1907; 186, 1916; and 187, 1916; *U. S. Dept. Agr. Farmers' Bull.* 940, 1918.

Northern Corn Rootworm[1]

Importance and Type of Injury.—Corn makes a slow growth, this checking of growth being most noticeable about the time the tassel appears. Plants are undersized and frequently fall over after a heavy rain. Small roots are eaten off and larger roots tunnelled by thread-like, white worms about ½ inch long (Fig. 197) with yellowish-brown heads,

Fig. 197.—Northern corn rootworm, *Diabrotica longicornis* Say, larva, five times natural size. (*From Ill. State Nat. Hist. Sur.*)

and six small legs on the fore part of the body. The skin of the body is somewhat wrinkled. This is perhaps the most important corn pest in the upper Mississippi Valley. The insects are so numerous that fields are practically sure to be heavily infested by the end of the second year in corn.

Plants Attacked.—The larvæ attack only corn, so far as known. The adults feed on a large number of plants that flower in summer and early fall.

Distribution.—The insect occurs in greatest abundance in the north part of the Mississippi Valley. It is not injurious in the southern states, and occurs in small numbers east of New York, and west of Kansas and Nebraska.

Life History, Appearance, and Habits.—The winter is passed only in the egg stage. The eggs are deposited in the fall in the ground around the roots of corn, and in no other known situation. They hatch rather late

[1] *Diabrotica longicornis* Say, Order Coleoptera, Family Chrysomelidæ.

in the spring and the larvæ work through the ground until they encounter the roots of corn; failing to do this, they die. They are not known to feed on any other plant, although probably they do feed to a slight extent on some native grasses. The worms burrow through the roots, making small brown tunnels. They become full-grown during July, leave the roots, and pupate in cells in the soil, the pupa being pure white and very soft. The adult stage (Fig. 198) is reached during the latter part of July and August. The beetles leave the soil and feed on the silk of corn, and the pollen of this and many other plants. The eggs are

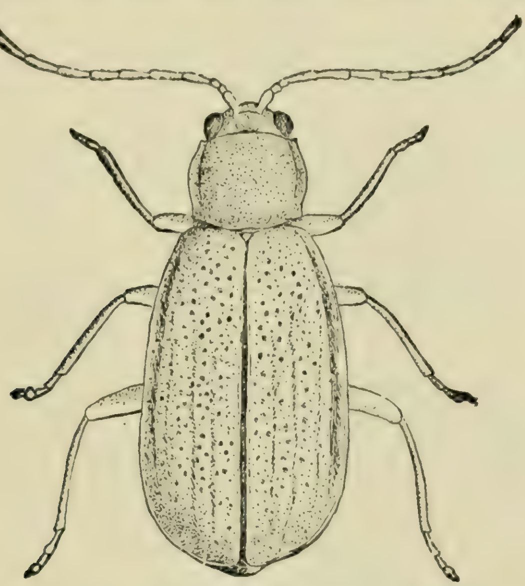

FIG. 198.—Adult of northern corn rootworm, *Diabrotica longicornis* Say, about ten times natural size. (*From Ill. State Nat. Hist. Sur.*)

deposited during September and October and nearly all of the beetles die at the time of the first heavy frost. They are about $\frac{1}{6}$ to $\frac{1}{4}$ inch long, of a uniform greenish to yellowish-green, and are very active, tumbling off the flowers or out of the corn silk when disturbed.

Control Measures.—As the eggs are laid only in corn fields and the larvæ feed, so far as known, only on the roots of this plant, rotation that will put any crop other than corn on the land for a period of 1 year will effectively clean out these insects.

References.—Eighteenth Rept. State Entomol. Ill., p. 135, 1891–1892; *Ill. Agr. Exp. Sta. Bull.* 44, 1896.

SPOTTED CUCUMBER BEETLE OR SOUTHERN CORN ROOTWORM[1]

Importance and Type of Injury.—Corn fields infested with this insect start growth in a normal way, and the plant begins to show the effect of the infestation when from 8 to 20 inches tall in the North, or much earlier in the South. From then on, the plant makes a very poor

[1] *Diabrotica duodecimpunctata* (Fabricius). Order Coleoptera, Family Chrysomelidæ.

growth, or none at all, and frequently dies. Sometimes the heart of the plant is killed by the larvæ, the lower leaves remaining green. As when attacked by the northern corn rootworm, the larger plants will fall after heavy rains. Examination of the plants will show the roots tunnelled and eaten off by larvæ about $\frac{1}{2}$ to $\frac{3}{4}$ inch in length, with yellowish-white, somewhat wrinkled bodies, six very small legs, and brownish

FIG. 199.—Larva of the spotted cucumber beetle or southern corn rootworm, *Diabrotica duodecimpunctata* (Fabricius), about five times natural size. (*From Ill. State Nat. Hist. Sur.*)

heads (Fig. 199). In addition to the injury to the roots, the lower part of the stalk will usually be bored through by the grubs.

Plants Attacked.—This insect has been taken from a very large number of plants, including more than 200 of the common weeds, grasses, and cultivated crops. It goes by several names, according to the food plants and is perhaps best known as the twelve-spotted cucumber beetle. It is also frequently called the overflow worm, and the bud worm.

FIG. 200.—Adult, spotted cucumber beetle, *Diabrotica duodecimpunctata* (Fabricius), about six times natural size. (*From Ill. State Nat. Hist. Sur.*)

Distribution.—The insect is widely distributed, occurring over the greater part of the United States east of the Rocky Mountains in Southern Canada and in Mexico. It is more abundant and destructive in the southern part of its range. The variety *tenella* extends into New Mexico, Arizona and California.

Life History, Appearance, and Habits.—This insect passes the winter in the form of a yellowish or yellowish-green beetle about $\frac{1}{4}$ inch long, with 12 conspicuous black spots on the wing covers (Fig. 200). The head is black, and the antennæ, which are about one-half to two-thirds as long as the body, are dark or nearly black. The beetles hibernate in nearly any kind of shelter, but seem to prefer the bases of plants which are not entirely killed down by the frost. They become active very early in the spring, flying about during the first days when the temperature reaches 70° F. or above. The females deposit their eggs in the ground around the bases of plants. The young larvæ on hatching bore in the roots of plants and the underground parts of the stem. They become full-grown during July. The insect has two generations in the southern part of its range and at least a partial second generation is produced in the North.

Control Measures.—It is extremely difficult to prevent damage to corn by these insects, as the eggs are frequently laid in the fields after the corn is up, and there is no method by which infested soil can be cleaned of the larvæ. About the most effective method is late planting on land which has been plowed early in the spring or in the fall, and cultivated before planting, so that all vegetation has been kept down. In certain seasons when the beetles have been very abundant, fields handled in this way have been practically the only ones to escape injury. Rotation of crops is of no value in controlling this species. The injury is usually most severe during wet years, or the first season following wet years, and is also often serious on land that has been overflowed during floods, or in drainage areas along the rivers where levees have broken. This may be due to the female beetles' preferring such a situation in which to lay their eggs, or to the fact that they are attracted to the rank vegetation which generally follows an overflow.

References.—*U. S. Dept. Agr. Farmers' Bull.* 950, 1918; *S. Car. Agr. Exp. Sta. Bull.* 161; *Eighteenth Rept. State Entomol. Ill.*, p. 129, 1891–1892.

Grape Colaspis[1]

Importance and Type of Injury.—Corn that has been planted on clover sod will sometimes wilt when the plants are about 6 to 10 inches high. The plants may die, or merely be greatly retarded in growth. An examination of the roots and soil about them will show numerous, curved, fat-bodied, very short-legged grubs from ⅛ to

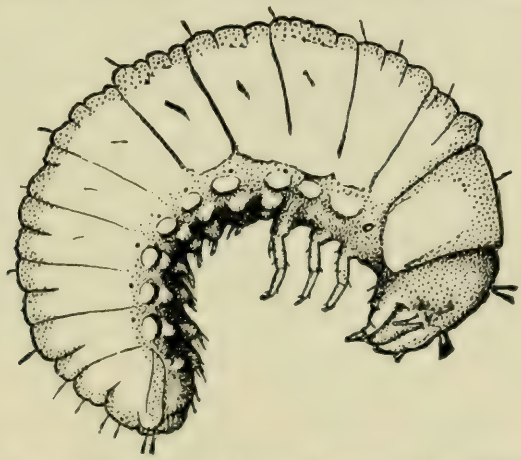

Fig. 201.—Larva of the grape colaspis, *Colaspis brunnea* (Fabricius), about fifteen times natural size. (*From Ill. State Nat. Hist. Sur.*)

⅙ of an inch in length (Fig. 201). Injury is most severe during late May and early June, and usually on corn following clover sod.

Plants Attacked.—Adults of this insect have been found on a number of crops including timothy, June grass, grapes, strawberries, beans, clover, buckwheat, potatoes, cowpeas, muskmelons and apples. Its habit of feeding on grape has given it the common name of grape colaspis. It is also known as the clover rootworm.

Distribution.—This beetle ranges throughout eastern North America and into Arizona and New Mexico.

[1] *Colaspis brunnea* (Fabricius), Order Coleoptera, Family Chrysomelidæ.

Life History, Appearance, and Habits.—So far as known, the winter is passed in the young larval stage. The larvæ are active early in the spring, and generally become full grown during the first part of the summer; in central Illinois, by about June 15. They pupate in the earthen cells in the soil and emerge during July as pale-brown elliptical beetles (Figs. 202, 253). The body of the beetle is about $\frac{1}{6}$ inch long and covered with rows of evenly spaced punctures. The adults fly about freely in the field and, as above stated, are very general feeders. Mating takes place and eggs are deposited in midsummer about the roots of several of the above mentioned food plants, but particularly on those of timothy, grape, and clover. There is only one generation of the insect each year.

FIG. 202.—Adult of the grape colaspis, *Colaspis brunnea* (Fabricius), about fifteen times natural size. Line shows natural size. (*From Ill. State Nat. Hist. Sur.*)

Control Measures.—Injury by this insect frequently occurs on spring-plowed red-clover sod, or spring-plowed timothy, but seldom where such ground is broken in the fall. Injury to corn has rarely been recorded following crops other than clover or timothy. A rotation that will avoid putting corn on spring-plowed clover or timothy sod will nearly always prevent injury by this insect.

Reference.—*Twenty-third Rept. State Entomol. Ill.*, p. 129, 1891–1892.

CORN ROOT APHID[1]

Importance and Type of Injury.—Corn infested by the corn root aphid, and its ever-attendant ant, will germinate normally, and the plants will reach a height of from 3 or 4 to 6 or 10 inches, when growth becomes

[1] *Anuraphis maidi-radicis* (Forbes), Order Homoptera, Family Aphididæ.

greatly retarded, especially during dry years. The plants often take on a yellowish or reddish tinge to the leaves. An examination of the field will show numerous small ant hills around the injured corn plants, and small brownish ants tunneling along the corn roots. Clinging to the corn roots will be found many bluish-green aphids, about the size of pinheads, when full-grown, the younger aphids being much smaller.

Plants Attacked.—This species of aphid is known to infest the roots of a number of different grasses, several weeds, particularly smartweed, and cotton, on which also it is a serious pest. A very similar species[1] occurs on the roots of aster.

Distribution.—The insect is common throughout the corn- and cotton-growing areas east of the Rocky Mountains.

Life History, Appearance and Habits.—The winter is passed, at least in the northern part of the country, only in the egg stage. These eggs (Fig. 203, *D*) are collected in the fall by the small brown corn field ants[2] and stored in their nests over winter. The ants (Fig. 203, *E*) pile the eggs in their nests, and move them about according to moisture and temperature conditions in the soil. In the early spring, about the time the young smartweed plants begin to appear in the field, the aphid eggs begin hatching. The ants seem instinctively to know that the young aphids must have something to feed on, and carry them to the roots of the smartweed and some of the grasses on which the aphids feed. Here the young aphids insert their beaks and suck the sap, growing rather rapidly, and in about 2 or 3 weeks become full-grown (Fig. 203, *B*) and begin giving birth to living female young. These young in turn begin giving birth to others after a period of from 8 days to 2 weeks. Only female aphids appear during the summer months. During July and August, winged individuals (Fig. 203, *A*) will frequently make their appearance on the roots, and will sometimes crawl to the surface of the ground, and fly to other fields, thus spreading the infestation. Local distribution of the aphid in the field, is almost entirely dependent on the corn field ants. This aphid is never found on roots except where attended by the ants, and if placed on the surface of the ground is apparently helpless so far as finding a place to feed is concerned. An ant finding one of these aphids, however, immediately picks it up, carries it underground, and places it on the roots of some of its food plants. The aphids apparently have been dependent on the ants so long that they have entirely lost the faculty of taking care of themselves. This interrelation between the ant and the aphid is one of mutual benefit, as the aphid is protected and kept by the ant where a supply of food is accessible; while the ant, in turn, derives a large part of its food from the sweet sticky exudation known as *honeydew* given off from the anal opening of

[1] *Anuraphis middletoni* (Thomas).

[2] *Lasius niger americanus* Emery, Order Hymenoptera, Family Formicidæ.

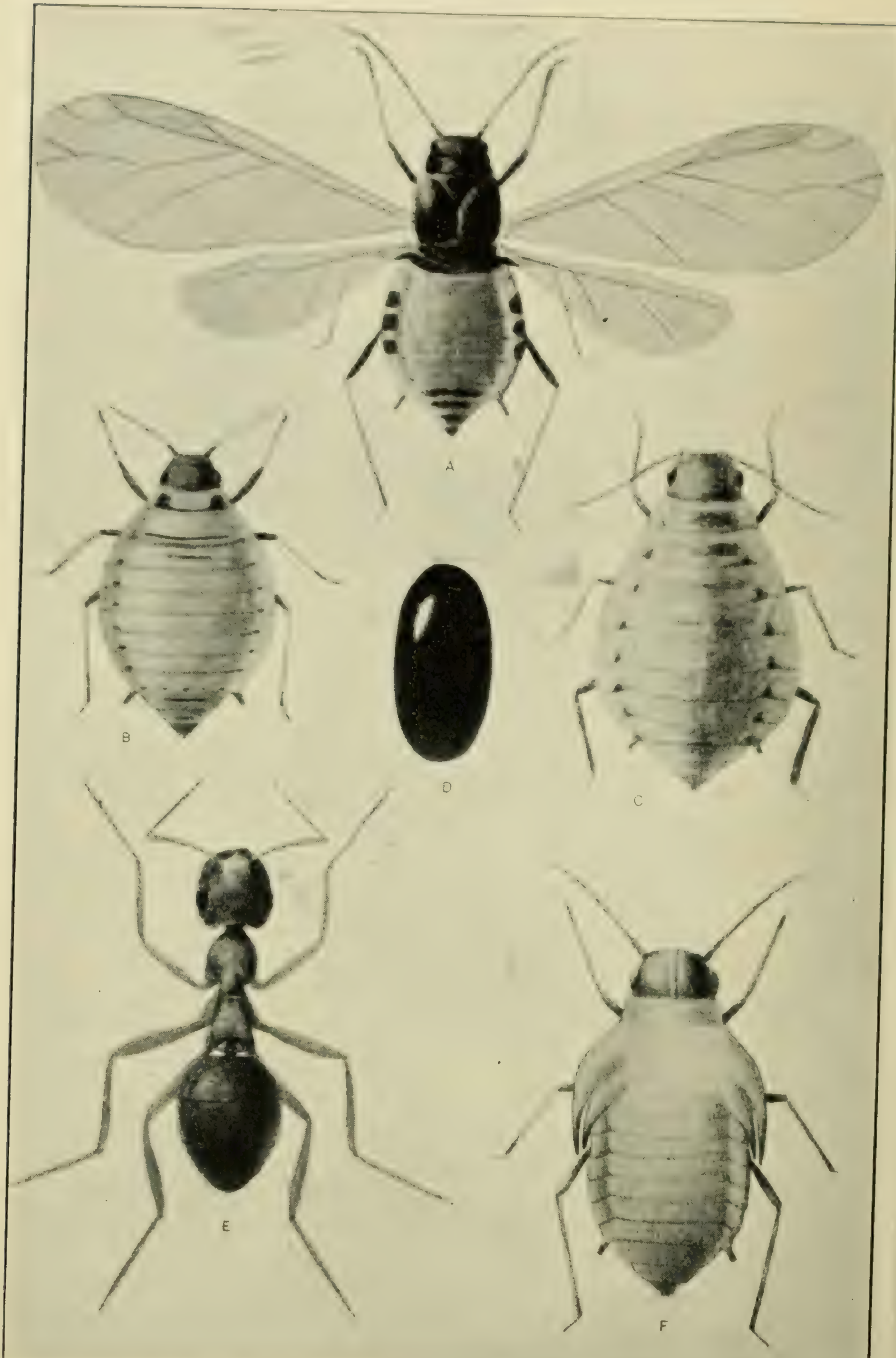

FIG. 203.—The corn root aphid, *Anuraphis maidi-radicis* (Forbes). *A*, the winged ovoviviparous female; *B*, the common wingless ovoviviparous female; *C*, the oviparous

the aphid. The ants act as though they knew the importance of preserving the eggs of the aphids over winter and that corn is the favorite food of these aphids. They will carry the aphids for some distance in order to pasture them on the roots of corn. In one instance under observation, the ants moved 156 feet from a timothy meadow in to the third row of a field of corn, carrying with them not only their own young, but also a large number of aphids which they began pasturing on the corn roots.

While only the female aphids are present in the fields during the summer, on the approach of cold weather these females give birth to different forms which consist of wingless true males and females. These mate, and the females (Fig. 203, *C*), instead of giving birth to young, lay dark-green shiny eggs, dying shortly afterward. The eggs are gathered up by the ants and stored in their nests during the winter.

Control Measures.—Extensive experiments have been carried on to find a treatment which could be applied to seed corn that would repel the corn field ants and thus prevent their placing the corn root aphids on the roots of young corn. Owing to the fact that soil is one of the best deodorants, most of the chemicals which have been used for treating the seed have not proved effective. One of the most effective treatments of this sort has been to moisten the seed thoroughly with a solution made by stirring 3 to 4 fluid ounces of oil of tansy into 1 gallon of wood alcohol, and moistening, but not wetting, the corn seed with this solution before planting. Some injury is likely to occur if cool, wet weather follows planting of such treated seed.

The best and most effective method of combating these aphids is a measure directed not against the aphids, but against their attendant ants. This consists of thorough deep cultivation of the soil early in the spring before planting. The land should be plowed 6½ to 7 inches deep, followed by two or three deep diskings at about 3-day intervals. The object of this heavy cultivation is to break up, scatter and destroy the ant nests in the soil. If the field is plowed to a depth of only 4½ or 5 inches, many of the lower chambers of the ant nests will not be thrown out in the furrow; 6-inch plowing, however, throws out about 95 per cent of the ant nests, and the disking, following this, breaks up and scatters the young of the ants and their aphids, so that they are not able to reestablish their nests in time to cause injury to the young corn. This treatment will also drive many of the ants out of the fields, as has been shown by watching at night the margins of fields where such treatments have been given.

References.—*Ill. Agr. Exp. Sta. Bulls.* 178, 1915; and 130, 1908; *U. S. Dept. Agr. Farmers' Bull.* 891, 1917.

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female, occurring only in autumn; *D*, the egg of the latter; *E*, the corn field ant (*Lasius niger americanus* Emery); and *F*, the nymph of the winged female. All much enlarged; actual size of aphids near that of the letters beneath these figures. (*From Ill. State Nat. Hist. Sur.*)

ARMY WORM[1]

Importance and Type of Injury.—Corn under 8 inches in height that is attacked by army worms will usually have the leaves eaten off entirely. With larger corn, the midrib of the leaves will sometimes be left, but the center of the young stalk is so eaten out that it dies. The dark-green worms (Fig. 204), up to 2 inches in length, with white stripes on the sides

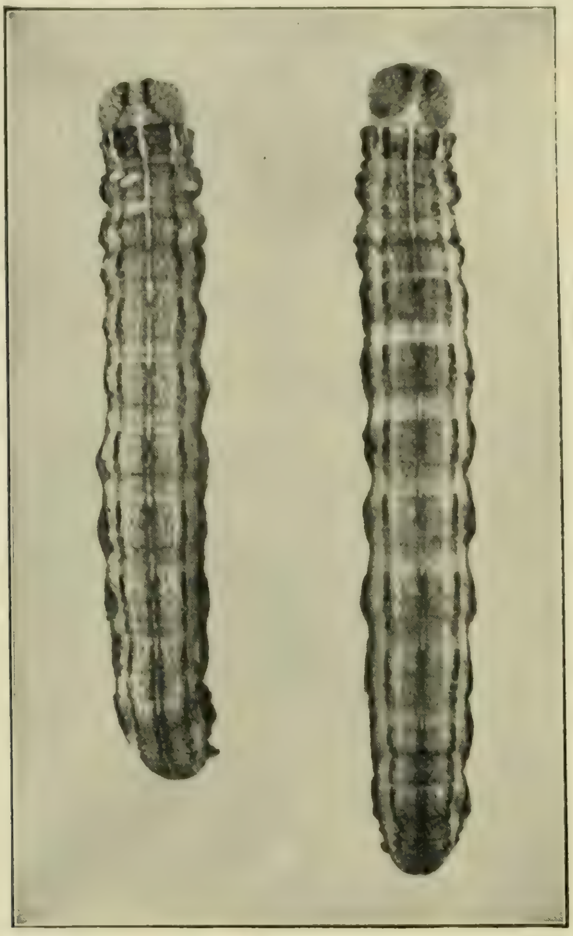


FIG. 204.—Full-grown army worms, *Cirphus unipuncta* (Haworth), the left one showing eggs of a tachinid fly parasite attached to the skin. Twice natural size. (*From Ill. State Nat. Hist. Sur.*)

and down the middle of the back, will be found hiding under clods and stones or in the center leaves of the plant during the day. The damage usually starts at the sides of the field, where the worms have moved in from some other crop.

Plants Attacked.—All grass crops especially corn, timothy, millet, blue grass, and small grains; and many other plants under stress of hunger.

Distribution.—United States, Canada, and many other parts of the world.

Life History, Appearance, and Habits.—The winter is passed mainly in the partly grown larval stage; but the fact that the moths are abroad very early in the spring in the northern states would indicate that some of

[1] *Cirphis unipuncta* (Haworth), Order Lepidoptera, Family Noctuidæ.

the insects winter as adults, or as pupæ, or that there is a spring flight northward from the southern part of the insect's range. The partly grown worms shelter in the soil about clumps of grasses, or under litter on the ground. They begin feeding early in the spring, become full-grown by the latter part of April in the latitude of central Illinois, and pupate just below the surface of the soil. The pupæ are dark brown, about ¾ inch long, tapering sharply at the tail, and blunt at the head end. They remain in this stage for 2 weeks, or longer if the weather is cool, and then transform to uniform, pale-brown or brownish-gray moths with a wing expanse of about 1½ inches (Fig. 205). There is a single, small, more or less prominent, white dot in the center of each front wing. The moths are strong fliers, but remain hidden during the day, becoming active at night. They are somewhat attracted to lights, and strongly so to sweets or decaying fruit. The females lay their greenish-white eggs in groups on the lower leaves of grasses to the number of 500 or more. The leaf is generally folded lengthwise, and fastened about the eggs with a sticky secretion. The young worms are pale green in color, and have the looping habit of crawling until about half grown. They may often be found by thousands in fields of grass or small grains, and because of their habit of feeding at night, their presence is generally not suspected until the crop is nearly destroyed. When the food supply becomes exhausted in the fields where they have hatched, these caterpillars move out in hordes or armies and attack crops in near-by fields. These crawling masses of worms have given them their common name. On becoming full-grown, the worms are nearly 2 inches long, of a dark-green color, with a narrow broken stripe down the center of the back and three light stripes on the sides, the lower one being of a yellow shade. They then enter the ground and change to the pupal stage, emerging as moths in from 14 to 20 days. There are from two to three generations each year. The larvæ of the first generation do most of the damage, in June in the latitude of central Illinois. The larvæ of the last generation are abundant in late August and September.

Fig. 205.—Army worm. Adult moth, natural size. (*From Ill. State Nat. Hist. Sur.*)

Control Measures.—One of the most effective methods of controlling an outbreak of army worms is to poison them by scattering a poison-bran mixture in the fields where they are feeding, or across the line of march of the worms when they are leaving fields where food is scarce. A very good bait for this purpose can be made as follows:

25 pounds of dry bran
3 gallons of water
2 quarts of cheap molasses
1 pound of sodium arsenite or Paris green or white arsenic

The water, molasses, and sodium arsenite should be well stirred together and then mixed with the bran so that every flake of bran is moistened. Only sufficient water should be used to make a crumbly mixture that will just hold together when tightly squeezed in the hand. If the sodium arsenite is not available, 1 pound of Paris green may be substituted; in which case, it should be mixed dry with the bran, and the water and molasses added later. Paris green and white arsenic are not quite as effective as the sodium arsenite.

This poison-bran bait should be scattered in the late afternoon, by hand or by using an end-gate seeder, at the rate of about 8 pounds to the acre. This will mean sowing about as thinly as possible. An application of this bait will often clean up a very heavy army-worm infestation.

Where the worms are advancing from one field to another, they may be stopped by plowing deep furrows in front of their line of advance and dragging a log or keg of water back and forth in the furrow until a very fine dust mulch has been worked up. The worms tumbling into this furrow will be unable to crawl up the steep dusty side, and will be crushed by the passage of the log. Post holes may be dug in the bottom of such a furrow to trap the worms, but it is usually better to omit the post holes and keep the drag in motion until the worms have ceased traveling.

Army-worm outbreaks usually originate in fields of small grain or grasses, especially where there is a very rank growth of vegetation, or where the grain has fallen down and lodged. Such situations should be watched, especially during May, and if the young worms are found, the poison bran bait should be applied immediately.

The army worm is preyed upon by a number of insects, especially certain parasitic flies,[1] which lay their eggs on the backs of the worms, mostly on the fore part of the body (see Fig. 204, upper worm and Fig. 37). The young maggots hatching from these eggs bore into the worms and kill them. They are also preyed upon by several ground beetles and certain parasitic wasps. Perhaps the most efficient insect enemy of the army worm is an extremely small, black, wasplike insect[2] that deposits its eggs inside the eggs of the army worm. The other parasites attack the worms when they are partly, to nearly fully grown, and thus prevent an excessive increase in the next generation, but do not kill the worms until after most of their feeding has been done. The egg parasite, on the other hand, by preventing the eggs from hatching, stops all damage by these insects.

References.—*N. Y.* (*Cornell*) *Agr. Exp. Sta. Bull.* 376, 1916; *Jour. Agr. Research, Vol.* 6, p. 799, 1916; *U. S. Dept. Agr. Farmers' Bull.* 731, 1916; *Illinois Nat. Hist. Survey, Ento. Series, Circ.* 7, 1921; *State Entomol., S. Dak., Circ.* 24, 1921.

[1] Tachinid flies, Order Diptera, Family Tachinidæ.

[2] *Telenomus minimus* Ashmead, Order Hymenoptera, Family Scelionidæ.

Cutworms[1]

Importance and Type of Injury.—There are a great many species of cutworms and the type of injury by the different species varies. In most cases, plants that are attacked will be cut off just above, at, or an inch or two below the surface of the soil (see Fig. 278). Most of the plant will not be consumed, but merely eaten at the point where it was cut off. A few species climb the stems of plants and eat off the leaves. In most

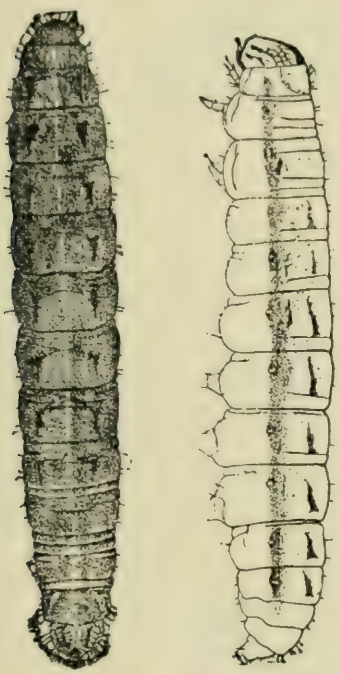


Fig. 206.

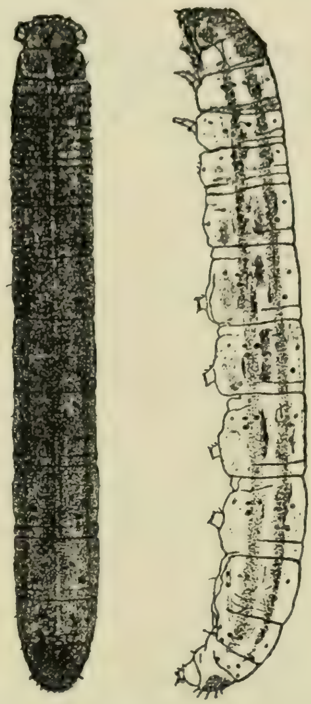


Fig. 207.

Fig. 208.

Fig. 206.—Larva of the spotted cutworm, *Agrotis c-nigrum* (Linné), dorsal and side view, somewhat enlarged. (*From Ill. State Nat. Hist. Sur.*)

Fig. 207.—Larva of the black cutworm, *Agrotis ypsilon* Rottemburg, dorsal and side view, somewhat enlarged. (*From Ill. State Nat. Hist. Sur.*)

Fig. 208.—Larva of the glassy cutworm, *Sidemia devastator* Brace, dorsal view, somewhat enlarged. (*From Ill. State Nat. Hist. Sur.*)

cases the smooth, brownish, greenish, or nearly white, well-fed-appearing worms (Figs. 206, 207, 208, 209) will be found hiding in the soil close to the stems of the plants which they have cut off.

Plants Attacked.—Nearly all plants, except those with hard, woody stems are fed upon by cutworms. Some of the crops most seriously injured are corn, beans, cabbage, cotton, tomatoes, tobacco, and clover.

Distribution.—Cutworms of various species are of world-wide distribution. Certain species are confined largely to southern, and others to northern, climates, some prefer dry conditions, while others are most abundant in wet areas or overflowed land.

Life History, Appearance, and Habits.—The majority of cutworms pass the winter in the partly grown, to fully grown larval stage. Some, how-

[1] Many species of Order Lepidoptera, Family Noctuidæ.

ever, hibernate as adults, and others as pupæ, in the soil. In typical cases, the worms remain as small larvæ in cells in the soil, under trash or in clumps of grasses during the winter. They start feeding in the spring and continue growth until early summer, when they change in the soil to a brown pupal stage and later to the adult or moth stage (Fig. 210). With most of our common species, there is but one generation a year; a few species have two generations; and, in others, the generations are so broken up that adults may be found at almost any time from late spring

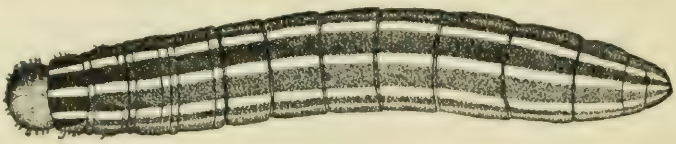


FIG. 209.—Larva of the bronzed cutworm, *Nephelodes emmedonia* Cramer, dorsal view somewhat enlarged. (*From Ill. State Nat. Hist. Sur.*)

to midfall. The eggs of most species are laid on the stems of grasses and weeds, or behind the leaf sheath of such plants. Certain of the moths, notably the black cutworm,[1] lay their eggs on low spots in the field, or land that has been subject to overflow. Certain others lay their eggs on the bare ground, or on ground that has been somewhat packed by the passage of vehicles or animals. The larvæ in most cases remain below the surface of the ground, or under clods or other shelters, during the day, and feed at night.

FIG. 210.—Adult of the clay-backed cutworm, *Feltia gladiaria* Morrison, slightly enlarged. (*From Ill. State Nat. Hist. Sur.*)

Some of the more important species are: The pale western cutworm,[2] a species which has caused losses to small grains amounting to millions of dollars annually in some of the western states and Canada. This species cannot be controlled by the use of poisoned baits because it feeds chiefly underground.

The black cutworm[1] (Fig. 207) is a species that is commonly very abundant in low areas in fields and on overflow lands. This species, which is of world-wide distribution, is difficult to control by the use of poison baits.

[1] *Agrotis ypsilon* Rottemburg.

[2] *Porosagrotis orthogonia* Morrison.

The spotted cutworm[1] (Fig. 206) is another species of general distribution throughout North America, Europe, and Asia. It feeds on a great variety of plants and sometimes assumes a climbing habit. This species can be controlled by the use of poisoned baits.

The variegated cutworm[2] (see Fig. 263) is found throughout most of the cultivated parts of the earth. It is said by Crosby and Leonard to have the widest range of food plants of any of the cutworms, damaging field and garden crops, greenhouse plants, many flowering plants, and a number of trees and shrubs, including evergreens. In the north part of the Mississippi Valley, it is often associated with the true army worm. It is perhaps the most common cutworm feeding on clover and alfalfa in this part of the United States. It is easily poisoned.

The glassy cutworm[3] (Fig. 208) is common in the northern United States and Canada. It is mainly a feeder on field crops, especially grasses. The larvæ feed below the surface of the ground and cannot be controlled by poison baits.

The bronzed cutworm[4] (Fig. 209) sometimes becomes very abundant on field grasses, grains, and in pastures. It is a northern species and is a surface feeder.

Several species of cutworms have been given the name of army cutworms. These are *Chorizagrotis auxiliaris*, *C. agrestis*, *C. introferens*, and *Agrotis fennica*. The first three are common in the western states and Canada. The last is generally distributed in the northern United States, and Europe. They are all surface feeders. Others frequently climb plants and cut off the leaves. There are many other species of nearly equal importance (see pp. 397 and 434).

Control Measures.—The species of cutworms which attack the plant above or at the surface of the ground, including the climbing cutworms, may be controlled very effectively by the use of the poison-bran bait described for the control of the army worms (see p. 319). Those species that feed mostly below the surface cannot be controlled by the use of poisons. Where the fields have already been planted, it is often possible to sow the bran effectively by attaching boxes to the sides of a saddle and scattering the poison while riding across the field. An end-gate oat seeder has sometimes been used for this purpose, but it is usually difficult to set this machine so that it will not distribute too large amounts of the poison.

The eggs of many species of cutworms are laid very largely in grass lands. One of the best methods of avoiding damage by these insects is to rotate the crops in such a manner that corn is not planted on sod

[1] *Agrotis c-nigrum* (Linné).

[2] *Lycophotia margaritosa saucia* Hübner.

[3] *Sidemia devastator* Brace.

[4] *Nephelodes emmedonia* Cramer.

ground unless such sod has been broken early in the fall or during late summer. Summer plowing will prevent the moths from laying their eggs on such land. There is no practical method of cleaning up land once it is infested, except by the use of the poisoned bran against such species as feed above the ground. Where the underground species are abundant, a special study of conditions will have to be made, as no general recommendations will apply.

Cutworms are subject to attacks by other insects, especially by certain flies which lay their eggs on the backs of the worms, and by ground beetles. They are readily fed upon by many species of birds, and the eggs are attacked by certain small wasp-like parasites.

References.—*S. Dak. Agr. Exp. Sta. Extension Circ.* 38, 1922; Crosby and Leonard, "Manual of Vegetable-garden Insects," p. 260, 1918; *Dom. Canada, Dept. Agr. Div. Entomol. Bull.* 3, 1912.

Sod Webworms[1]

Importance and Type of Injury.—Corn on spring-plowed sod land will sometimes be cut off near the surface of the ground in much the same manner as where attacked by cutworms. An examination of the surface of the ground will show a loose silken web containing bits of dirt leading to a short, silk-lined tunnel in the ground, usually at the base of the plant (Fig. 211). Short, rather thick-bodied, usually spotted and coarsely haired worms, from ¼ to a little over ½ inch long, will be found in these silk-lined tunnels (Fig. 212). Frequently the cut-off corn plants are dragged to the tunnel.

Plants Attacked.—The sod webworms, as their name implies, feed on the grass plants, including corn, more particularly on blue grass, timothy, and other pasture and field grasses. Certain closely related species attack clovers.

Distribution.—There are a number of species of sod webworms occurring in different parts of the United States and Canada.

Life History, Appearance, and Habits.—The sod webworms, which are injurious to corn, pass the winter in the larval stage in silk-lined nests in grass and sod lands. They become active early in the spring, feed in much the same way as cutworms, although eating the leaves to a greater extent, and become full-grown during late June and July. The moths (Fig. 213) are, in most cases, pale brown in color, and have a pronounced projection from the front of the head. They vary in size from ½ to nearly 1 inch in length. The projection from the head, which is formed by the labial palps held close together, has given them the name of snout moths. One will frequently stir them up when walking across grass lands. They have a very quick, jerky, zigzag flight, usually going only a rod or two, when they alight and hide by crawling down into the grass. The moths lay their eggs around the lower parts of grass stems soon after emerging, the young larvæ hatching and feeding for a short time before going into hibernation. With most species, there are two or three generations each season. The corn webworm[2] has only one generation a year, so far as known.

Control Measures.—The most effective control measure for these insects, is early fall plowing of sod land which is to be used for corn the next season. Adults of the sod webworm will not lay their eggs in plowed ground, so that this measure will effectively prevent damage. If it is impossible to plow early, the land should be plowed in the fall and harrowed to expose the hibernating worms to the weather and their natural enemies. If fields are damaged early in the spring to such an extent

[1] Species of the subfamily Crambinæ, Order Lepidoptera, Family Pyralididæ.

[2] *Crambus caliginosellus* Clemens.

that they should be replanted, the replanting should be made between the rows and the first planting of corn left as long as possible, undisturbed, to serve as food for the worms until the second planting becomes too large for them to cut off. Poison-

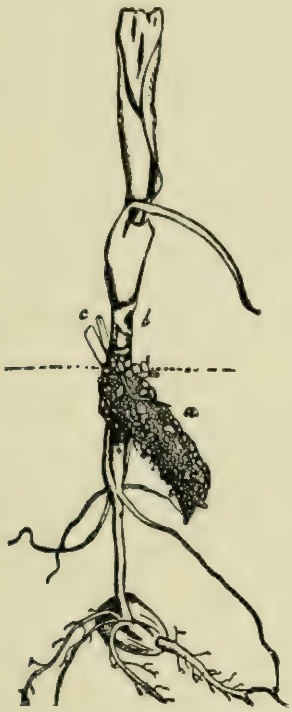


Fig. 211.—Corn plant injured by a sod webworm, *Crambus luteolellus* Clemens: *a*, silk-lined tunnel in the soil; *b*, gnawed surface of stalk; *c*, tip of severed leaf drawn into mouth of nest. (*From Ill. State Nat. Hist. Sur.*)

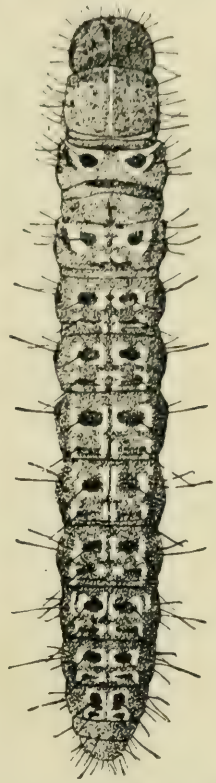


Fig. 212.—Larva of a sod webworm, *Crambus mutabilis* Clemens, dorsal view, about four times natural size. (*From Ill. State Nat. Hist. Sur.*)

bran bait, as recommended for cutworms and army worms, is of no value against the sod webworms.

References.—*U. S. Dept. Agr. Farmers' Bull.* 1258, 1922; *Twenty-third Rept. State Entomol., Ill.*, p. 30, 1905; *Jour. Agr. Research*, Vol. 24, pp. 399–425, 1913.

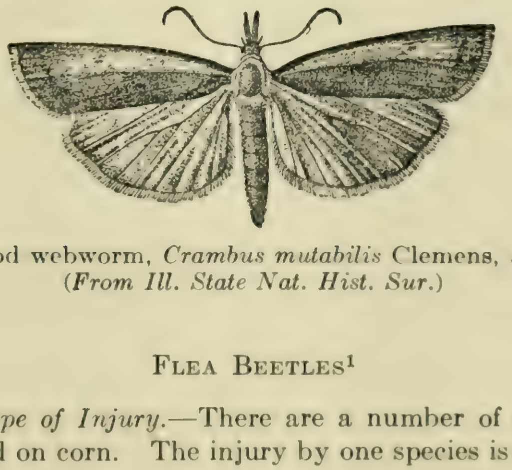


Fig. 213.—Adult of a sod webworm, *Crambus mutabilis* Clemens, about twice natural size. (*From Ill. State Nat. Hist. Sur.*)

Flea Beetles[1]

Importance and Type of Injury.—There are a number of species of flea beetles which occasionally feed on corn. The injury by one species is typical of that caused

[1] Order Coleoptera, Family Chrysomelidæ.

by all. Corn makes very little growth. The green portion of the leaf is eaten, giving the whole plant a bleached appearance; growth is retarded, and the leaves wilt even during wet weather. Small to very small, shining, roundish, black, brown, or grayish-black beetles will be found feeding on the leaves. These beetles jump readily when approached. The hind legs are distinctly enlarged and thickened. Occasionally the injury will be caused by somewhat elongated dark green beetles with white stripes on the back (Fig. 189).

Fig. 214.—Adult of the corn flea beetle, *Chætocnema pulicaria* Melsheimer, about twenty times natural size. (*From Ill. State Nat. Hist. Sur.*)

Plants Attacked.—Nearly all kinds of plants are attacked by adult flea beetles. The species that are most injurious to corn also feed on millet, sorghum, broom corn, sweet potato, sugar beet, oats, morning glory, bull nettle, and cabbage.

Distribution.—Flea beetles of various species are of world-wide distribution. The corn flea beetle, and morning-glory flea beetle, perhaps the two most injurious species on corn, occur generally over the eastern part of the United States. Their place is taken in the west by the western cabbage flea beetle.

Life History, Appearance, and Habits.—Practically all of the flea beetles injurious to corn, with the probable exception of the pale-striped flea beetle, which has already been described on p. 302, pass the winter in the full-grown-beetle stage. They shelter largely along bushy fence rows, road sides, or the edges of woodlands. Some of the species prefer shelters afforded under trees. In the spring, the insects become active as soon as vegetation is well started. The beetles after mating, lay their eggs on the leaves of plants, or in the ground about the roots or underground stems. The larval habits of most species are not well known. Nearly all the damage to corn is caused by the adults feeding on the leaves. This occurs during the first 2 or 3 weeks after the corn has come up, and the injury is usually most severe during cold seasons, when the growth of the corn plant is slow, thus giving the flea beetles a long period during which they are attacking the small plants. In seasons when the weather is favorable for growth, the plant usually outgrows the attack of these insects. Several of the species attacking corn have a single generation, while others produce two generations each season. Only the overwintering adults are of importance, however, so far as their injury to corn goes. The species which most commonly cause injury to corn are the western cabbage flea beetle,[1] the corn flea beetle[2] (Fig. 214), the toothed flea beetle,[3] the sweet-potato flea beetle[4] (Fig. 215), and the smartweed flea beetle.[5] Several other species are of minor importance as corn feeders.

Fig. 215.—Adult of the sweet-potato flea beetle, *Chætocnema confinis* Crotch, about twenty-five times natural size. (*From Ill. State Nat. Hist. Sur.*)

Control Measures.—In combating flea beetles on corn, keeping the fields free from weeds is probably of first importance. Larvæ of some of the species injurious to corn feed on the roots of weeds and grasses, and the adults on the leaves of these plants as

[1] *Phyllotreta pusilla* Horn, Order Coleoptera, Family Chrysomelidæ.
[2] *Chætocnema pulicaria* Melsheimer.
[3] *Chætocnema denticulata* Illiger.
[4] *Chætocnema confinis* Crotch.
[5] *Systena hudsonias* Forster.

well as on corn. Fields that have been kept clean the previous season, both in the field and around the margins, are very seldom injured by flea beetles. The next important control measure is planting sufficiently late so that the corn will make a quick growth. This, of course, cannot always be done, but fields that are particularly subject to injury, such as low ground where there has been an abundance of vine growth the previous season, should be handled in this way, especially during cool springs. If the beetles are working on the corn, frequent cultivation will drive them temporarily from the plants, and prevent continued feeding, thus lessening damage. In cases of severe infestation, it is possible to catch large numbers of the beetles by attaching vertical sheets covered with sticky tanglefoot to the cultivator frames in such a manner that the sheets pass between the corn rows and just above the surface of the ground. Such measures will seldom be necessary if frequent cultivation can be given. According to McCulloch, arsenate of lead dusts are effective and practical when the infestation is local in the field.

Reference.—Twenty-third Rept. State Entomol., Ill., pp. 109–111, 1905.

Grasshoppers[1]

Importance and Type of Injury.—Corn is seldom attacked by grasshoppers until the plant has reached a height of 20 or more inches. Plants that are attacked have the tips of the ears and the leaves eaten and the stalks presenting a general ragged or bare appearance. Grasshopper injury usually starts on the sides of the field, as the insects seldom originate in the corn field.

Plants Attacked.—Various species of grasshoppers attack nearly all cultivated and wild plants.

Distribution.—Grasshoppers occur over the entire world.

Life History, Appearance, and Habits.—Grasshoppers that attack corn practically all pass the winter in the egg stage. These eggs are laid in packet-like masses nearly 1 inch long and from ½ to 1½ inches below the surface of the soil (Fig. 216). They are mainly deposited in uncultivated ground such as field margins, pasture land, and roadsides. In the middle-western and western states, they are frequently laid in considerable numbers in clover and alfalfa fields. Occasionally corn is slightly injured by some of the so-called bird grasshoppers,[2] these being the large species, from 2 to 3 inches long, which one sees about the fields in the early summer, or late spring. These species pass the winter in the adult stage. With the more common and typical species, the eggs (Fig. 217) hatch somewhat late in the spring. In the latitude of central Illinois, hatching begins in late May and continues until July. The young hoppers (Fig. 79, *E*) differ but little from the adult, except in size and the fact that they lack wings. They change their skins several times in the course of their growth, and at the last molt acquire full-sized, usable wings. With most of the species which injure corn, growth is completed from the middle of August to the first of September. The

[1] Many species of the Order Orthoptera, Family Locustidæ.

[2] *Schistocerca americana* Drury and *Schistocerca alutacea* Harris.

FIG. 216.—Differential grasshopper, *Melanoplus differentialis* Thomas, laying eggs in soil; enlarged. A part of the soil has been removed to expose the abdomen and the egg mass. (*From U. S. D. A. Farmers' Bull.* 691.)

FIG. 217.—A clump of grama grass, showing a number of grasshopper egg masses among the stems and roots (indicated by arrows). (*From S. Dak. Agr. Exp. Sta. Bull.* 172.)

adults, however, continue to feed until the first heavy frost. The eggs are mainly deposited during the latter part of September and October.

The species which have caused the greatest injury to corn are the ones described below. The red-legged grasshopper[1] is a medium-sized species, about 1 inch long when full-grown, of a general brownish-red color. The tibiæ of the hind legs are red with black spines. This species is abundant throughout most of North America, but less so in the southwestern states.

The lesser migratory grasshopper[2] is rather small, being only 1 inch long when in the adult stage. The wings are brownish with a line of dark spots down the wing covers. The hind tibiæ are often red, but on the whole, not as highly colored as in the red-legged grasshopper.

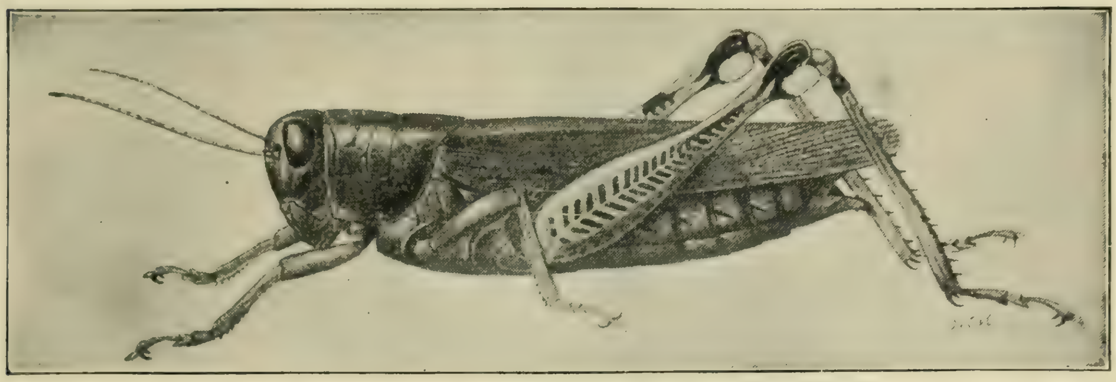


Fig. 218.—Adult of the differential grasshopper, *Melanoplus differentialis* Thomas, side view, enlarged about one-half. (*From Ill. State Nat. Hist. Sur.*)

However, the two species closely resemble each other in appearance. This species is common throughout the United States and Canada, and has somewhat of a migratory habit, large flights having occurred in a number of cases. The Rocky Mountain locust, or migratory grasshopper, which caused very heavy damage to crops in the Missouri Valley from 1874 to 1880, is closely related to this species. So far as known, the Rocky Mountain grasshopper is now entirely extinct, no specimens having been taken for a number of years. The olive or differential grasshopper,[3] is one of the largest species, occurring in great numbers over the eastern part of the United States. The adult (Fig. 218) when full-grown is 1½ inches in length, and of a brownish or olive-green color. The hind wings are clear or very faintly tinted. It is one of the most commonly destructive species in the Mississippi Valley.

The clear-winged grasshopper[4] (Fig. 219) is one of the more common western species, but occurs also in the eastern part of the country. It

[1] *Melanoplus femur-rubrum* DeGeer.

[2] *Melanoplus atlanis* Riley, Order Orthoptera, Family Locustidæ.

[3] *Melanoplus differentialis* Thomas.

[4] *Camnula pellucida* Scudder.

is of a light-brown color with darker spots and yellowish splotches on the sides. The hind wings are transparent with dark veins. It is one of the first grasshoppers to appear in the spring.

The Carolina grasshopper[1] is also frequently called the road-side grasshopper. It is a rather large species, being about 2 inches long when full-grown. It is brown in color, with specks of gray and red on the wing covers. The under wings are black, with distinct yellow margins. It is common throughout Mexico, the United States, and southern Canada, and is perhaps the best known of any of our common grasshoppers because of its habit of frequenting roadsides.

FIG. 219.—Adult of the clear-winged grasshopper, *Camnula pellucida* Scudder, about twice natural size. (*From Ill. State Nat. Hist. Sur.*)

The two-striped grasshopper[2] is a widely distributed species occurring over most of North America from Hudson Bay into Mexico, including the Pacific Coast. It is considered by Blatchley[3] as one of the most common grasshoppers in clover fields. The adult is medium-sized, robust, olive-brown above and pale yellow to greenish yellow beneath. A narrow yellow stripe extends from each eye along the sides of the pronotum. It is an early-summer species and has usually disappeared from the fields by mid-September.

A number of other species of grasshoppers cause injury to corn, but the ones mentioned are by far the most important. All of these species pass the winter in the egg stage.

Control Measures.—Grasshopper control consists of three distinct measures: the first, to destroy the eggs in the fall and winter, and the other two to combat the grasshoppers at the time they are attacking

[1] *Dissosteira carolina* (Linné).

[2] *Melanoplus bivittatus* Say.

[3] BLATCHLEY, "Orthoptera of Northeastern America," Nature Pub. Co., Indianapolis, 1920.

crops. The first of these measures consists of fall plowing or disking of areas in which the grasshoppers have laid their eggs, thus exposing the eggs to the action of the weather and to birds during the winter and early spring. Plowing or disking to a depth of 4 inches is usually sufficient to destroy the eggs. This is often quite effective, especially in the West, where there are areas of uncultivated land interspersed with the cultivated areas.

The most effective method of grasshopper control is by the use of a poison bait. Different baits have been recommended. All of them, however, consist of a base of bran or sawdust, and poison, mixed with water and syrup, salt, fruit juices, or other materials as attrahents. A the present time, after a great deal of careful work to test the effectiveness of different baits, it appears that syrup, particularly blackstrap molasses, or possibly soap, is the best material to use for attracting grasshoppers to the poison bait. A very effective bait can be made in the following proportions:

25 pounds bran, or half bran and half sawdust, or hardwood sawdust alone;
1 pound of sodium arsenite, Paris green or white arsenic;
2 quarts of blackstrap molasses or other syrup.
Sufficient water to make a stiff mash, usually 2 or 3 gallons.

Mix the bran and poison together thoroughly, stir the molasses into the water, add to the poisoned bran and then mix until every flake of bran is moistened. In many cases, 2 or 3 ounces of amyl acetate, or three to six lemons, have been recommended to each 25 pounds of the above poison mixture. Under certain conditions it is evident that the odors of the fruit or fruit extracts, or of the amyl acetate, act as a distinct attrahent to the grasshoppers; but on the whole, it is doubtful if these materials will pay for their additional cost. Paris green or white arsenic can be used if sodium arsenite is not available. The ingredients for the bait should be thoroughly mixed together and the material scattered at the rate of about 8 or 10 pounds per acre. On the whole, the best results have been obtained where the poison has been applied early in the morning. Grasshoppers do not feed at night, and seem to take the bait most readily during the early part of the day and while it is fresh. Thousands of tons of poison baits have been used during the past few seasons, and, where properly applied, with very satisfactory results. According to Cooley, crops to the value of $2,500,000 were saved in one year in Montana by the application of $185,000 worth of poison bait.

Where for any reason it is impossible to poison grasshoppers by the use of baits, they may be trapped and killed in hopperdozers or hopper-catchers. The hopperdozer (Fig. 220) is merely a long, narrow, shallow trough, made of boards or metal, having a depth of 4 inches and being $2\frac{1}{2}$ to 3 feet wide and about 15 feet long, mounted on skids or runners

so that it can be drawn back and forth across the field by team or tractor. A vertical shield of boards, oil cloth, or metal extends to a height of 3 to 3½ feet at the back of the trough. The trough is partly filled with water, and sufficient kerosene is poured on top of the water to cover the surface with a film of oil. The grasshoppers, on flying up to avoid the passage of the trough, strike the shield at the back and fall into the pan where they are killed by the mixture of kerosene and water; or, if they hop out, are killed by the action of the kerosene on their bodies. There are several modifications of this hopperdozer, the most common of which are screen boxes constructed at the back of the vertical shield with a metal lip projecting at the front and bottom of the shield and extending back into the box. With this catcher, the hoppers strike

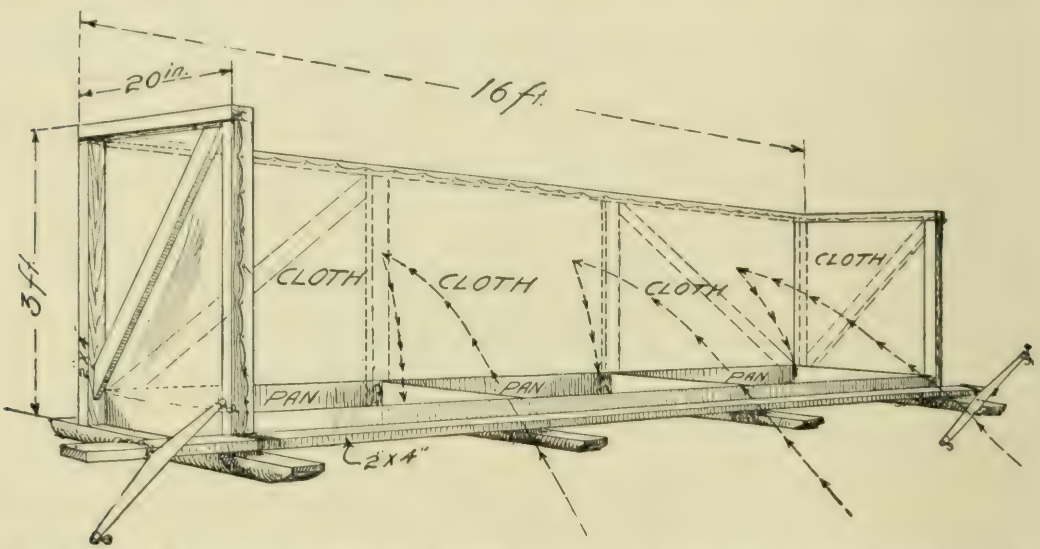


Fig. 220.—A machine for catching grasshoppers. A hopperdozer with cloth back, and pans for oil, in which the grasshoppers are killed as they are caught. (*From U. S. D. A. Farmers' Bull.* 747.)

the front of the shield, slide down to the metal lip, and are shot back into the screen box. No liquid is required in this type of catcher, and the grasshoppers may be scooped out of the box, sacked, dried, and used for chicken feed or hog feed, for which they are excellent. Both the hoppercatcher and the hopperdozer are quite effective in cleaning fields of hoppers.

As high as 4 to 8 bushels of grasshoppers per acre have been caught with these machines. When one considers that there would be over 200,000 grasshoppers in a bushel, and that it has been estimated by Morrill, that where grasshoppers are present at the rate of 17 per square yard, they will eat 1 ton of green alfalfa hay per day in a 40-acre field, it is seen that these machines are well worth operating in fields where grasshoppers are abundant. Some other types of catchers are used, but the two mentioned are by far the most effective.

References.—Minn. Agr. Exp. Sta. Tech. Bull. 141, 1914; *Colo. Agr. Exp. Sta. Bull.* 280, 1923; and *Extension Circ.*, Ser. 1, 180 A, 1921; *S. Dak. Agr. Exp. Sta. Bull.* 172, 1917; *U. S. Dept. Agr. Farmers' Bull.* 747, 1922; *Jour. Econ. Entomol.*, Vol. 7, p. 67, 1914; Vol. 10, p. 524, 1917; Vol. 11, p. 175, 1918; Vol. 12, p. 337, 1919; Vol. 13, pp. 232 and 237, 1920 and Vol. 14, pp. 138 and 281, 1921.

European Corn Borer[1]

Importance and Type of Injury.—The presence of the European corn borer is often indicated by corn stalks with the tassels broken or bending over. Other indications of its attack are: small areas of surface feeding on the leaf-blades, with fine, sawdust-like castings on the upper sides of the leaves or stalks; small holes in the stalks, often with slimy borings protruding from the holes; worms boring through the stem and along

Fig. 221.—A field of dent corn totally ruined by the European corn borer; Ontario, Canada, 1925. (*From Ill. Agr. Exp. Sta. Circ.* 321.)

the entire length of the ear and cob; numerous flesh-colored, inconspicuously-spotted caterpillars, from ½ to 1 inch long, boring in all parts of the stalks; and stalks sometimes so heavily infested that they fall or break off (Fig. 221).

Plants Attacked.—Nearly all herbaceous plants large enough for the worms to enter. The insect seems to prefer corn in the single-generation areas of the Middle West and in Ontario, although some of the common weeds, vegetables, flowers, and field crops are often found infested when such plants are grown in close proximity to badly infested corn fields. In the area in New England where the corn borer has two generations a year, the insect seems to prefer corn, dock, millet, sorghum, beets, cocklebur, pigweed, smartweed, dahlias, gladioli, and similar plants, even when such plants are not associated with corn. It has been found feeding on more than 200 kinds of plants.

[1] *Pyrausta nubilalis* Hübner, Order Lepidoptera, Family Pyralididæ. *U. S. Dept. Agr. Tech. Bull.* 59, 1928.

Distribution.—This insect is distributed over the greater part of Europe and parts of Asia. In North America, in 1927, the insect was confined to a large area in the New England states, another in eastern New York, and a third covering the territory in the United States and Canada adjoining the shores of Lake Erie, Lake Michigan, Lake Ontario and Lake Huron (Fig. 222). It is rapidly extending its range and will probably in time include the whole of the corn-growing area of North America.

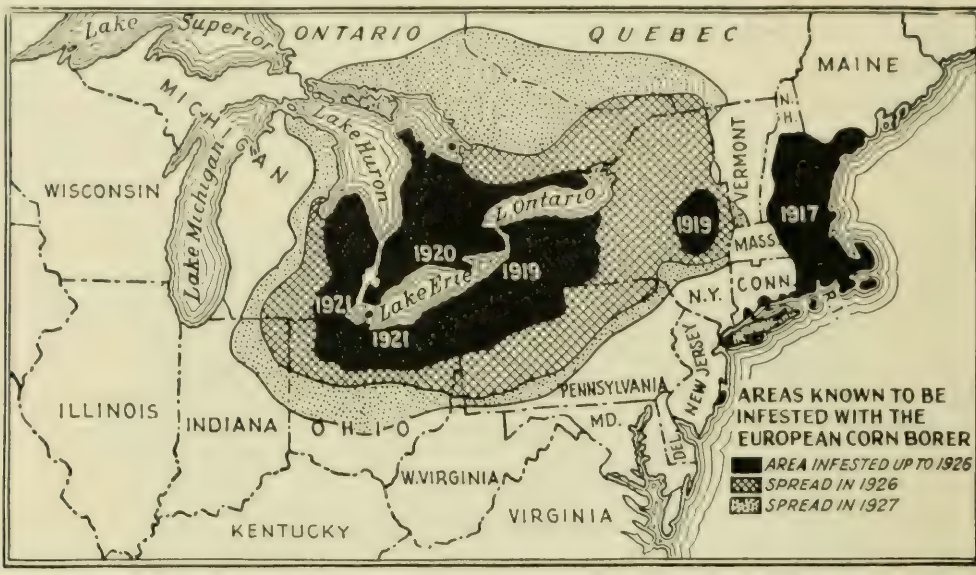


FIG. 222.—Map showing the known distribution of the European corn borer, Jan. 1, 1928. The figures show date of earliest discovery in various states as follows: 1917, first discovered in America, near Boston, Mass.; 1919, in eastern New York, near Schnectady and in western New York, near Silver Creek; 1920, in southern Ontario, near Port Stanley; 1921, in northern Ohio and southern Michigan. (*Original.*)

Life History, Appearance, and Habits.—This insect passes the winter in the form of a full-grown worm or caterpillar (Fig. 223), in the stems of the food plants on which it has been feeding. These worms are from $\frac{3}{4}$ inch to nearly 1 inch in length. The body is flesh-colored, rather inconspicuously marked with small, round, brown spots. They may be found in all parts of the stem and ear; but, especially in corn stalks, are most abundant, in winter, just above the ground surface. In the spring of the year, the caterpillar constructs a flimsy cocoon in its burrow, and in this transforms to a slender brown pupal stage. The moths (Fig. 224) begin emerging during June and continue to come out in the northern states until August. The adult female moths are a pale yellowish-brown with irregular darker bands running in wavy lines across the wings. The male moth is distinctly darker, having the wings heavily marked with olive brown. The moths have a wing expanse of about 1 inch. They are strong fliers, but move about mainly at night. The females lay their eggs (Fig. 225) in groups of 5 to 50 on the undersides of the leaves of their food plants. Each female will lay, on the average,

from 500 to 600 eggs; sometimes many more. The eggs ordinarily hatch in a week or less, depending on the temperature, and the young borers feed to some extent externally on the leaves, but soon bore into the larger parts of the leaf, the leaf stem, the stalk of the plants, or the ear. They continue to feed as borers until they are full-grown.

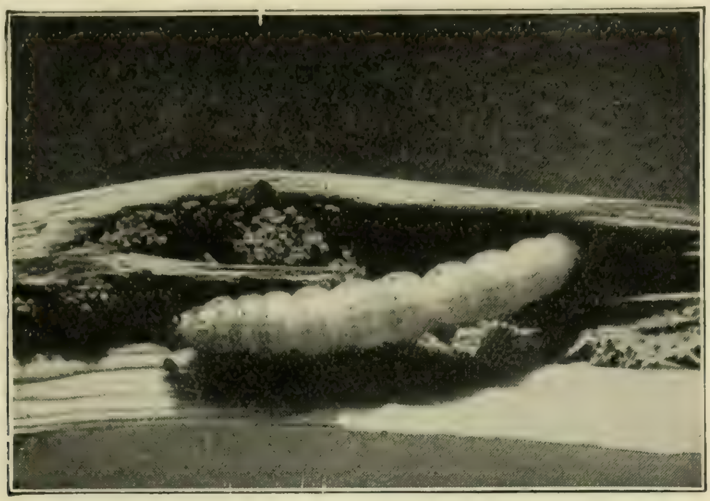


Fig. 223.—The larva of the European corn borer, about twice natural size. It is easily confused with the smartweed borer which is native to the United States. In the European corn borer the two spots on the back of each abdominal segment are usually much smaller than in the smartweed borer, and more widely separated, their distance apart usually exceeding the width of one spot. In the native species, the distance between the spots is usually less than the width of one spot. A faint stripe can usually be seen on the mid-dorsal line of the European corn borer. (*From Ill. State Nat. Hist. Sur.*)

The large numbers of them which frequently occur in a single plant, often causes the plant stem to collapse. Three hundred and eleven borers have been taken in a hill of corn containing four stalks, and forty-two have been taken from a single ear of field corn.

Fig. 224.—Adults of the European corn borer; female at left, male at right; slightly enlarged. (*From Mich. Agr. Exp. Sta. Circ.* 70.)

In most of the area now infested in North America the insect has a single generation a year, the larvæ becoming full-grown during August and September and, as above stated, remaining in the stems over winter. In the New England area, however, the insect has two generations. The moths appear during August and early September, and deposit eggs

which produce another generation of worms during the late summer and early fall. In both areas, hibernation takes place mainly in the full grown larval stage. In Europe, the insect has either one or two generations, the two generations occurring in the southern part of its range. While the insect has been known to be present in North America only since 1917, and was probably introduced into this country in shipments of broom corn from Italy or Hungary some time about 1908 or 1909, it has shown itself capable of being one of the most destructive, if not the most destructive, insect pest of corn.

Control Measures.—About the only effective control measure thus far developed consists in the destruction or utilization, during the fall, winter, or early spring, of all crop residues and plant refuse in which the borers may pass the winter. The most effective methods of control

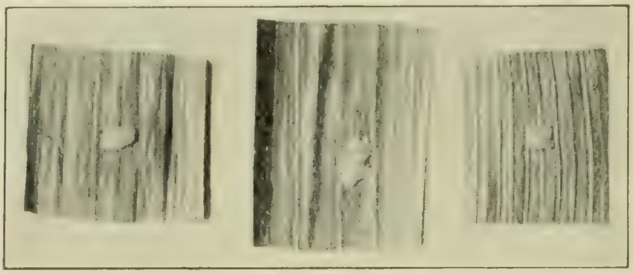


Fig. 225.—Egg masses of European corn borer on under side of corn leaves. About natural size. (*From Spencer and Crawford, Ontario Dept. Agr. Bull.* 295.)

are *clean* plowing under of all crop and weed refuse or raking together this plant refuse and burning. The borers are killed in corn that is cut and shredded or placed in a silo. Disking the fields or *ordinary* plowing under of corn stalks are of little value. Late planting of corn is of some value in preventing injury, in the single-brooded areas.

Other measures which may prove of considerable importance in controlling this insect are rotations in which a maximum acreage will be in crops not seriously affected. In general the legume crops have suffered very slightly, although some damage has been done to cowpeas. Soybeans, red clover, and alfalfa have had almost no damage from this insect. If shock fodder is fed to cattle in feed lots, all the refuse stalks should be cleaned up from the lots and burned by early spring, as it has been shown that many borers may come through the winter in such stalks and spread from them to fields planted in corn in the vicinity the next season. Where corn is cut for silage or shredded for fodder, the stubble should not be left over 2 inches high. Machines for cutting the corn close to the ground are being developed to leave only a 2-inch stubble. As corn is the favorite food plant among the cultivated crops, considerable damage to other crops may be avoided, in the one-generation area, if corn is planted at some distance from them. This holds

particularly true for beets, beans, spinach, rhubarb, celery, and outdoor flowering plants. All weeds should be kept down around roadsides and field margins.

References.—*Mass. Agr. Exp. Sta. Bull.* 189, 1919; *N. Y. (Cornell) Agr. Exp. Sta. Extension Bulletin* 31, 1919; *U. S. Dept. Agr. Farmers' Bull.* 1294, 1922; *U. S. Dept. Agr. Dept. Bull.* 1476, 1927; *U. S. Dept. Agr. Tech. Bull.* 53, 1927; *Ill. Agr. Exp. Sta. Circ.* 321, 1928.

Common Stalk Borer[1]

Importance and Type of Injury.—The common stalk borer usually injures corn around the margins of the field for from 2 or 3 to 20 rows into the field. Occasionally when fields are very weedy the previous year, the injury may extend over the entire

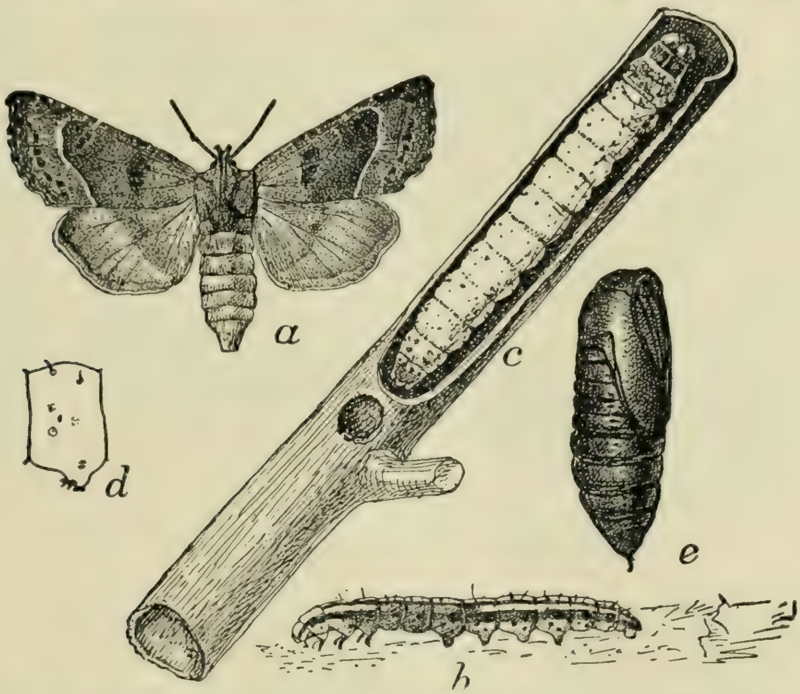


FIG. 226.—The Common stalk borer, *Papaipema nebris* Guenee; *a*, adult; *b*, half-grown larva, side view; *c*, full-grown larva in burrow; *d*, side of one segment of larva; *e*, pupa. All slightly enlarged. (*From Chittenden, U. S. D. A.*)

field. Stalks of corn attacked by this insect will show irregular rows of holes through the unfolding leaves. Plants will often show an unnatural growth, twisting or bending over, presenting a stunted appearance, and often not producing ears. Holes will be found in the sides of the stalks with moist castings being thrown out. Inside the stalks will be found very active, dark brown worms ranging from ¾ inch to nearly 2 inches in length. All but the larger of these worms (Fig. 226, *b*) have a single continuous white stripe down the back, with broken white stripes on the sides extending from the head about one-sixth the length of the body, and then starting again about one-third the way from the hind end of the body.

Plants Attacked.—This insect is almost a universal plant feeder, attacking and working in stems of any plants large enough to shelter it and soft enough so it can bore into them. It apparently prefers giant ragweed and corn in its later stages.

Distribution.—It is distributed generally throughout the United States east of the Rocky Mountains.

[1] *Papaipema nebris* Guenee, Order Lepidoptera, Family Noctuidæ.

Life History, Appearance, and Habits.—So far as known, the insect hibernates only in the egg stage, the eggs being laid during the fall on grasses and weeds. They hatch very early in the spring into the small, brown, white-striped caterpillars which frequently bore first into the stems of grasses, particularly blue grass on which the eggs are often laid. As the caterpillars grow, they attack the larger-stemmed weeds and grasses. They are extremely uneasy individuals, never seeming contented with their location, and frequently changing from the stem of one plant to that of another. This habit is responsible for their causing a much greater amount of injury than would be the case if they stayed in one plant. While the giant ragweed seems to be the favorite food of this insect, it will frequently leave these weeds for corn if the two are growing close together. The worms become full-grown during the latter part of July and the first of August, at which time they lose their striping, and are a plain dirty-grayish color (Fig. 226, *c*). They are then from 1½ to nearly 2 inches in length. They transform inside the stems of their food plants into a brown pupal stage (Fig. 226, *e*), and during the latter part of September, emerge as grayish moths (Fig. 226, *a*) with a wing expanse of a little over 1 inch. The front third of the wings is usually a dark grayish-brown, with several white spots. The hind wings are a pale gray-brown. There is considerable variation in the appearance of the adults. They mate and the females lay their eggs on grasses and weeds as above mentioned. Eggs have been taken on ragweed, dock, pigweed, burdock, and several grasses. There is only one generation a year.

Control Measures.—A thorough clean-up, preferably by burning over the margins of the fields during the fall and a clean-up and burning of all crop refuse is the best means of fighting this insect; in fact it is the only means which has offered any practical help in controlling the injuries. Clean cultivation of fields that will keep down weed growth is also of value.

References.—*Twenty-third Rept. State Entomol. Ill.*, p. 44, 1905; *Rept. State Entomol. N. J.* for 1905, p. 584, 1906

Lesser Corn-stalk Borer[1]

Importance and Type of Injury.—In the southern part of the United States, corn is sometimes injured by slender greenish worms boring into the lower part of the stalk and the heart of the plant. Corn under 18 or 20 inches high attacked by this insect becomes much distorted and curled, and frequently fails to produce ears or good stalks.

Plants Attacked.—Besides corn, the insect feeds on peas, beans, peanut, cowpeas, crab grass, Johnson grass, wheat, turnip, and probably several other crops.

Distribution.—The range of the insect is from Maine to southern California, but it is largely confined, so far as injury goes, to the more southern states. It is also found in Mexico, Central America, and South America.

Life History, Appearance, and Habits.—The insect hibernates in the larval, pupal, and adult stages, but usually in the southern states as a larva, which transforms to a pupa before spring. The moths (Fig. 227, *a*, *c*) emerge from the pupæ, or become active, early in the spring and lay their greenish-white eggs on the leaves of the plants on which the larvæ feed. The eggs hatch in about one week; the caterpillars (Fig. 227, *d*) feed at first on the leaves, but quickly burrow into the stems of corn and other plants. They eat into the heart of the unfolding leaves of the corn, sometimes killing it. The larvæ become full-grown in about 2 to 3 weeks. Their presence in the corn is indicated by masses of borings which are pushed out from the holes in the stalk. The insects leave their burrows when full-grown and spin silken cocoons (Fig. 227, *f*)

[1] *Elasmopalpus lignosellus* Zeller, Order Lepidoptera, Family Pyralididæ.

under trash on the surface of the ground, in which they change to brownish pupæ about 1/3 inch long. From these, the moths emerge in from 2 to 3 weeks. They have a wing expanse of nearly 1 inch. The front wings are brownish-yellow with grayish margins with several dark spots. In the female, the front wings are nearly black. A second generation is produced in all the southern states where this insect is injurious.

Control Measures.—As is the case with the common stalk borer, practically the only effective control is fall or winter clean-up of the fields and field margins. Winter plowing has given control in some cases, or is at least helpful in reducing the numbers of the insects in the field. Early planting also is recommended in some sections in the southern states as a control for this pest.

Reference.—U. S. Dept. Agr. Bur. Entomol. Bull. 539, 1917.

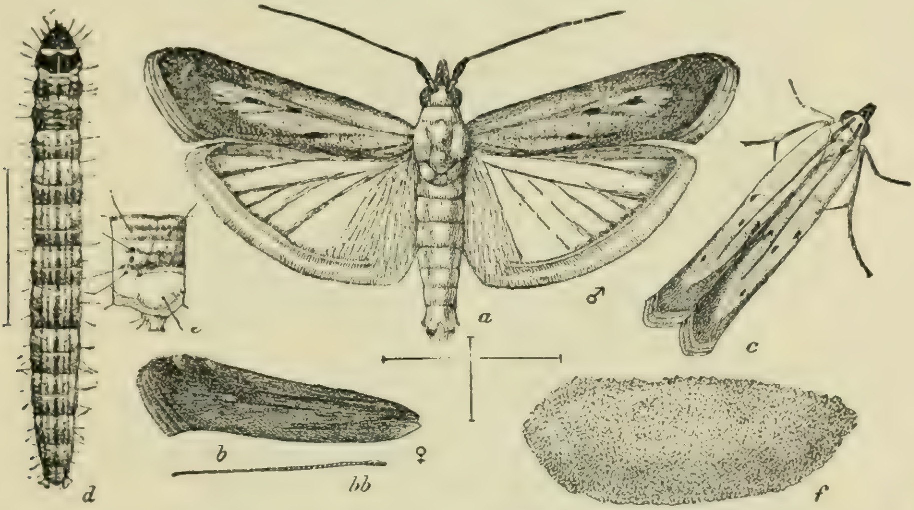


FIG. 227.—The lesser corn-stalk borer, *Elasmopalpus lignosellus* Zeller. *a*, male; *b*, forewing of dark female; *bb*, antenna of female; *c*, male at rest, *d*, larva, dorsal view; *e*, side view of a middle segment; *f*, cocoon. Lines indicate natural size. (*From Chittenden, U. S. D. A.*)

LARGER CORN-STALK BORER[1]

Importance and Type of Injury.—Corn infested by the larger corn-stalk borer is usually twisted and stunted, often with an enlargement of the stalk at the surface of the ground. The leaves will sometimes be ragged, showing many holes along the leaf which have been eaten out while it was still curled in the heart of the plant. Inside of the stalk will be found dirty, grayish-white worms about 1 inch in length when full-grown, conspicuously marked with many dark-brown spots (Fig. 228).

Plants Attacked.—The larger corn-stalk borer feeds principally on corn. It has also been taken on sorghum and Johnson grass.

Distribution.—This is a southern insect, damage being limited mainly to states from Maryland and Kansas on the north to, and including, the southern and southwestern states. The insect is found also in Mexico, and southward to South America.

Life History, Appearance, and Habits.—The winter is passed in the form of a full-grown larva. The insect will be found in the lower part of

[1] *Diatræa zeacolella* Dyar, Order Lepidoptera, Family Pyralididæ.

the stalk, just above the roots. It remains in the larval condition until early spring when it changes inside the stalk to a naked brown pupa, the larva having first made an exit hole to the outside of the stalk and covered this with a web of fine silk. The adult moths emerge from the larval burrows in midspring. These moths are of a general light straw color, with a wing expanse of 1¼ inches. They lay their eggs in clusters on the undersides of the leaves. The worms hatching from these eggs feed at first on the leaves, but soon enter the stalk, boring in the pith. They change from one plant to another, as does the common stalk borer. The first-generation worms become full-grown a little before midsum-

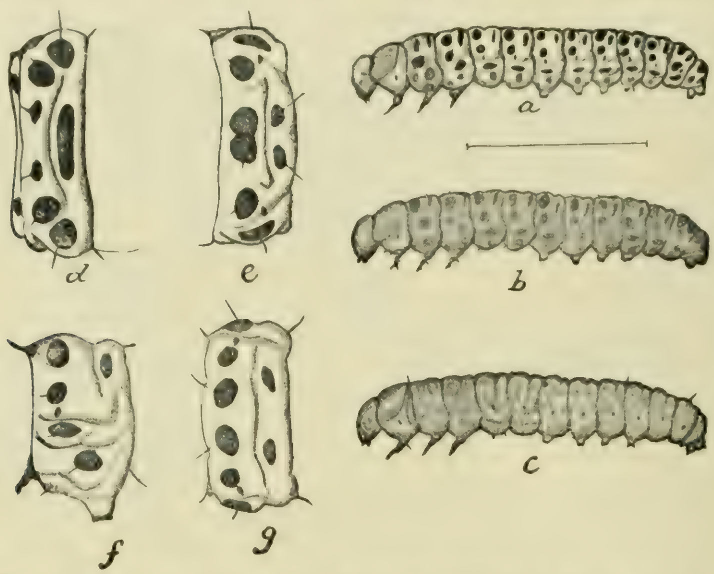


FIG. 228.—The larger corn-stalk borer, *Diatræa zeacolella* Dyar: *a*, *b*, *c*, color varieties of the larvæ; *d*, third thoracic segment; *e*, eighth abdominal segment; *f* and *g*, a middle segment in side and dorsal views. The line shows natural size. (*From Howard, U. S. D. A.*)

mer, and pupate inside the stalks. Those of the second generation reach maturity in the early fall and remain as larvæ during the winter. There are but two generations annually.

Control Measures.—As the insects hibernate in the stalks of corn and other food plants, a thorough cleaning up and burning of corn-stalk refuse and corn stubble during the winter is the most effective control measure. Rotation in which corn follows some other crop is also helpful in keeping down this insect. Late-fall and winter plowing will destroy most of the hibernating larvæ in the stalks.

References.—*Va. Agr. Exp. Sta. Tech. Bull.* 22, 1921; *N. Car. Dept. Agr. Bull.* 274, 1920.

GRASS OR RUSH BILLBUGS[1]

Importance and Type of Injury.—Corn from 8 to 20 inches in height, especially if planted on sod ground or bottom lands, will frequently show

[1] *Sphenophorus* (or *Calendra*) spp., Order Coleoptera, Family Curculionidæ.

rows of regular punctures, or areas eaten out across the leaves (Fig. 229). An examination of such plants will show that the injury has been done while the leaves were curled in the heart of the plant, and possibly will disclose small to medium-sized, black or clay-colored snout beetles feeding in the curl of the plant or on the stalk. These beetles (Figs. 229, 230) have a snout projecting from the front of the head about one-fourth as long as the body, the chewing mouth parts being located at the tip of this snout.

FIG. 229.—Billbugs: adults, larva, and characteristic injury, from adults feeding on corn. (*From Ill. State Nat. Hist. Sur.*)

Plants Attacked.—Grass billbugs feed mainly on grassy plants and on sedges and rushes growing in low swampy areas. Corn planted in such sod land may be very severely injured.

Distribution.—Several different species of billbugs feed on corn; taken together, they are generally distributed in grass and lowland areas throughout the United States.

Life History, Appearance, and Habits.—The species of billbugs found most commonly on corn in this country pass the winter mainly in the adult stage, although certain species, notably the wheat billbug,[1] occasionally hibernate in the larval stage. These hibernating larvæ pupate early in the spring in the situations where they have fed, and change to adult beetles by midspring. The overwintering adults become active at

[1] *Sphenophorus parvulus* Gyllenhal.

about the same time, and feed by chewing with their long beaks into the stems of plants, or in the heart of the plant where the leaves are unfolding. They are sluggish, slow-moving insects, which "play 'possum" when disturbed. The species commonly found on wheat and timothy are small, not over 1/4 inch in length by half as wide, and of a black color. Some of the species feeding in low lands are nearly 1 inch in length, being black or dark brown in color. One of the most destructive, the clay-colored billbug[1] (Fig. 120), is nearly 1 inch in length, and of a tan or bluish color. This species feeds as a larva on the club rush, or common cat-tail. The female beetles lay their eggs in the underground parts of the stems or roots of these plants, the eggs being deposited during the early summer. The larvæ grow slowly, reaching maturity in most cases in early fall, and transforming in the locations where they have fed into the pupæ and later to the adult stage.

So far as known, none of the species has more than one generation a year. The life history of many of the species is not well known. Some of the smaller species attack wheat as well as corn, notably the wheat billbug. *Sphenophorus pertinax* (Olivier) is another large species frequently found on corn on bottom lands.

Control Measures.—Grass billbugs are difficult to control except by rotation of crops that will bring corn on land which has not been in sod during the previous season, or which has not been recently broken out of swamp lands. Crops other than grasses are not attacked by these insects, and the small grains are only rarely seriously infested. Early-fall or late-summer plowing and the thorough working down of the infested land in the fall will drive out most of the hibernating beetles, little injury to corn generally occurring where this practice has been followed.

References.—Sixteenth Rept. Ill. State Entomol., 1890 and *Twenty-second Rept.*, 1903; *U. S. Dept. Agr. Bur. Entomol. Bull.* 95, Part II, 1911 and Part IV, 1912; *U. S. Dept. Agr. Farmers' Bull.* 1003, 1919.

Corn Billbug[2] and Maize Billbug[3]

Importance and Type of Injury.—Infested corn has somewhat the same appearance as that fed upon by the grass billbugs; showing regular transverse rows of holes across the leaves. Later in the season, the stalks will be distorted, dwarfed, and twisted. Many plants that are injured send forth an abundance of suckers. An examination of infested plants will show burrows inside the stalk, and white, fat-bodied, legless grubs feeding inside these burrows. The grubs are of a dingy white color about 2/5 inch in length, with brown heads (see Fig. 229).

[1] *Sphenophorus æqualis* Gyllenhal.
[2] *Sphenophorus callosus* Olivier, Order Coleoptera, Family Curculionidæ.
[3] *Sphenophorus maidis* Chittenden.

Plants Attacked.—Corn is the principal food of the maize billbug, although it breeds also in some of the large swamp grasses, mainly in gama grass (*Tripsacum dactyloides*). The corn billbug seems to prefer rice, chufas (*Cyperus* spp.), and corn, in the order named.

Distribution.—Confined largely to the southern states.

Life History, Appearance, and Habits.—The insects hibernate in the adult stage (Fig. 230), many of them inside the larval burrows in the corn. A few leave these burrows and shelter in coarse grasses, or other litter, about the fields. The beetles become active in the spring about the time of corn planting. They are about ½ inch in length, of a dull black color with raised markings on the wing covers and back of the thorax. The body tapers towards both ends, and a black snout projects from the head about one-third as long as the body. They frequently become so covered with mud that it is hard to see them on the surface of the ground. They lay their eggs in cavities gouged in the heart of the young corn plants by the beak of the beetle, frequently killing the young plants in the process of egg laying or feeding. After the plants become 15 to 20 inches high, but few of them are killed in this way. The eggs hatch into the white larvæ above described. They continue to grow slowly during the summer, becoming full-grown during the first part of August. They then descend to the lower end of their burrows, usually to the underground part of the stalk, and there construct a cell in which they change to the pupal stage. They become adults during September, but most of them remain in the corn stalks until the following spring. There is but one generation of the insects each season.

Fig. 230.—Adults of the maize billbug, *Sphenophorus maidis* Chittenden, feeding on corn. (*From Kans. Agr. Exp. Sta., Tech. Bull.* 6.)

Control Measures.—Crop rotations in which corn does not follow corn are of great help in preventing injury by these insects. The greater part

of the beetles spend the winter in the bases of the old corn stalks. Raking up and burning these stalks is only partially effective, as the infested stalks break off and the underground parts containing the beetles are left in the ground. Winter plowing, where it can be practiced, is of some value. In the South, early planting is recommended.

References.—*U. S. Dept. Agr. Bur. Entomol. Bull.* 95, Part IV, 1912; *Kan. Agr. Exp. Sta. Tech. Bulletin* 6, 1920; *N. Car. Agr. Exp. Sta. Tech. Bulletin* 13, 1917.

Corn Leaf Aphid[1]

Importance and Type of Injury.—Corn infested by this insect shows numerous greenish or greenish-blue aphids in the curl of the leaves and upper parts of the stalk. Leaves are sometimes entirely covered with these aphids. Winged and wingless individuals will be found during the summer. Infested corn leaves are frequently mottled with yellowish or reddish-yellow patches.

Plants Attacked.—The insect has been found on corn, millet, broom corn, sorghum, and Sudan grass. It shows a preference for sorghums. It winters on barley in the Southern States and California.

Distribution.—The insect is common throughout the corn-growing areas of the United States and Canada, being more abundant in the south. Its range extends throughout the world.

Life History, Appearance, and Habits.—Our knowledge of the life history of this insect is incomplete. In the north-central states, it appears in corn fields about midsummer, but is present in the South during the winter months. Thus far, only the winged and wingless females are known. No observations have been made on the winter stages in the northern states, and it is not known whether this species passes the winter in the egg stage in this section, or whether it migrates up from the south during the spring and early summer. The female aphids cluster in large numbers on the plants, sometimes almost entirely covering the leaves. Some winged females are present throughout the summer. The insects feed until they are killed by a heavy frost, or the drying up of their food plants. Corn is only occasionally slightly injured by these insects in the northern states. In the South, they are somewhat more destructive. The worst damage by the insect occurs from the discoloration of the leaves, due to a bacterial infection which follows the punctures of the aphid's beak. This frequently lowers the grade of broom corn, but is of little consequence on field corn.

Control Measures.—No practical control measures for this insect are known.

Reference.—*Twenty-third Rept. State Entomol. Ill.*, p. 123, 1905.

Chinch Bug[2]

Importance and Type of Injury.—Losses caused by chinch bugs in the United States have been extremely heavy. Webster estimated a total damage in this country of $350,000,000 from 1850 to 1900. In one year, chinch bugs destroyed more than $7,000,000 worth of crops in thirteen heavily infested Illinois counties. The first indication of the presence of chinch bugs in the field will often be the wilting and drying out of the infested corn. Usually this occurs on the side of the field next to small

[1] *Aphis maidis* Fitch, Order Homoptera, Family Aphididæ.

[2] *Blissus leucopterus* (Say), Order Hemiptera, Family Lygæidæ.

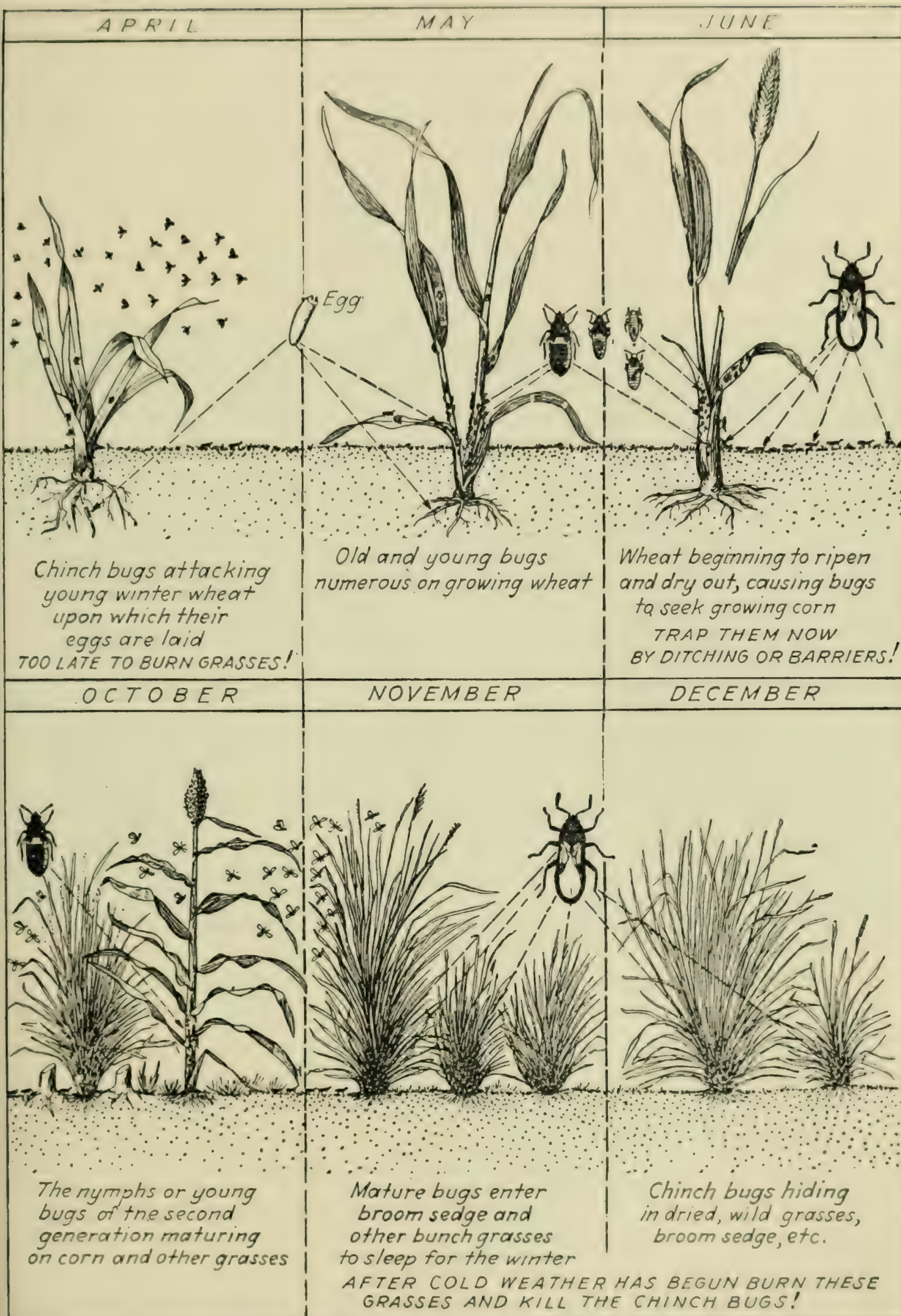
grains. Occasionally injured plants may appear in any part of the field. Small black-and-white to gray-and-white or red insects will be found behind the sheaths of leaves, or in the soil about the base of the plant, often with slender beaks inserted in the plants from which they suck the sap. At small-grain harvest, hordes of these insects will be found crawling over the ground from cut grain into fields of corn or other growing grass crops.

Plants Attacked.—The insect feeds only on the plants belonging to the grass family. This includes all of our cultivated and wild grasses, corn, and small grains.

Distribution.—The chinch bug has been found throughout the United States, in southern Canada, in Mexico and in Central America. Its areas of greatest destructiveness are in the Mississippi, Ohio, and Missouri river valleys.

Life History, Appearance, and Habits.—The chinch bug (Fig. 231) hibernates only in the adult stage, the full-grown insect being about $\frac{1}{6}$ to $\frac{1}{5}$ inch in length, with a black body. The white wing covers are each marked with a triangular black patch at the middle of their outer margins. The legs are reddish to reddish yellow. The insect gives off a vile odor, when crushed, that is somewhat distinctive and always remembered by one who has smelled it. They hide away in almost any kind of shelter during the winter; but in the Middle West, chiefly along the south side of hedge rows, bushy and grassy fence rows or roadsides, and the south and west edges of woodlands. Where the clump-forming native prairie grasses are present, the bugs seem to prefer them for winter quarters. They have been taken, however, in a great variety of different shelters. The adult chinch bugs remain in their hibernating quarters until the temperature reaches a point above 70° F. for several hours during which the sun is shining. They may move about on warm days earlier in the spring, and occasionally mating takes place before they leave their hibernating quarters. When the above-mentioned temperature is reached on sunny days, they crawl up the stems of grasses, or other plants about their hibernating quarters and take flight, usually going to fields of small grain. Here they feed by sucking the sap from wheat, rye, oats, or barley, and the females deposit their eggs behind the "boots" of the lower leaves; or, if the ground is loose, upon the roots. The insects mate repeatedly, laying a few eggs each day for 3 weeks or 1 month, an average of about 200 eggs being laid by each female. These eggs hatch into small, very active, reddish bugs with a band of white on the back just behind the wing pads. They become dark as they grow older, and at the last molt, acquire full-sized wings. The bugs require about 30 to 40 days to complete their development. This usually does not occur until after small-grain harvest, especially that of wheat. They are dependent for their food supply on the sap of growing grass plants. It is, therefore, necessary

FIG. 231.—Chart showing seasonal history of chinch bug, *Blissus leucopterus* (Say), in the Central States. During the winter from December to February, bugs are hibernating at the edges of woodland, under fallen leaves and in bunches of grass and other shelters. In February or March, flight to young grain begins and continues until about the middle of May. In June and July the bugs crawl in great numbers from ripening wheat to young



succulent corn and at that time may be trapped in ditch barriers or by lines of creosite. Becoming adult about Aug. 1, they scatter among the corn plants, where eggs are laid and the second generation is begun. When these become adult from Sept. 23 to the early part of November, they find hibernating quarters, where they remain until spring. (*After U. S. D. A. Farmers' Bull.* 1498.)

for them to leave the dried stubble field when grain is cut. As they are still wingless, they usually migrate on foot to fields of corn, or grasses, where they complete their growth. The adult stage is reached during the early part of the summer to midsummer. The adults may remain in the situations where they are feeding, but usually fly for a few days after reaching the adult stage. Mating again takes place, and the eggs of a second generation are deposited on corn or grasses. The first-generation adults die by mid-September, and the second-generation nymphs complete their growth by the approach of cold weather. During the warm sunny afternoons of early fall, they fly from the corn fields to their winter quarters. As they are seeking warm, sheltered places at this time, most of them will congregate on the south and west sides of the situations which afford them shelter during the winter.

Two forms of the chinch bug occur. In the more common form the adult has black and white, well-developed, usable wings. In the less common form, occurring more generally in the eastern states and in Canada, the adults, although winged, have the wings so short and rudimentary that they cannot be used for flight. The short-winged form feeds more on grasses and does not have the pronounced migration from one food plant to another that occurs in the case of the long-winged form in the large grain-growing sections.

Control Measures.—Certain methods of control have been found of value in combating these insects, no one of which, however, can be entirely depended upon to clean up a chinch-bug outbreak. As the chinch bug feeds only on plants of the grass family, the growing of non-grass crops is of great value during years of chinch-bug outbreaks, not only because these crops will not be injured in the least by the bugs, but also because the larger the area in such crops, the less will be that in which the chinch bug will find feeding and breeding places.

It has also been found possible to reduce the injury by chinch bugs to corn by planting a strong-growing legume crop such as soybeans or cowpeas in the hills of corn. These plants are not of themselves repellent to the chinch bugs, but by producing a dense shade around the base of the corn plants, they give a condition which is unfavorable to the bugs, and which they avoid. Chinch bugs are primarily sun-loving insects and always seek the thinner parts of fields, or poorer stands of any of the crops on which they feed. Certain varieties of corn have been found very resistant to the attacks of second generation chinch bugs, but no corn is chinch-bug proof.

Large numbers of the bugs may be killed in the winter time by burning them out in the shelters where they are hibernating. This method is particularly effective in the states west of the Mississippi, where the majority of the bugs pass the winter in the clump-forming grasses which are easily burned. It is less effective in the states to the east, where the

bugs shelter to a greater extent in woodlands and along hedgerows, roadsides, and fences.

One of the most effective methods of combating the chinch bugs is trapping them at the time of small-grain harvest when they are traveling on foot from small-grain fields to fields of corn, or other growing grass crops. This may be done by constructing a barrier line around the margin of the small grain field along which the bugs can be stopped and killed or trapped. One of the most effective barriers is made by pouring a narrow line of crude creosote (Fig. 232) along the brow of a smooth

Fig. 232.—Creosote barrier protecting corn field from migrating chinch bugs. The field of small grains from which chinch bugs are migrating is beyond weeds at the right. (*From Ill. State Nat. Hist. Sur.*)

ridge thrown up with the plow around the margin of the infested small-grain field. The creosote should be poured on the side of the ridge next the small grain so the bugs will be climbing the ridge as they approach it. A strip of creosote making a line 1 inch wide on the soil is sufficient to turn the bugs, as they are strongly repelled by the odor of this chemical. Daily applications of the creosote are necessary for a period of 10 days to 2 weeks; 50 gallons of creosote are usually sufficient to maintain ¼ mile of barrier for a season. Post holes 18 inches to 2 feet deep may be dug on the inner or small-grain side of this line, the tops of these holes flared and dusted. The bugs may be caught in such holes by the bushel as they travel along the creosote line seeking a place where they can escape from the field. Dusting of the top of the holes makes it impossible for the

bugs to obtain a foothold upon it, and they roll into the holes. A small amount of kerosene poured into the holes will kill all of the bugs wet by it.

Recently it has been discovered that the bugs can be killed along the barrier lines by placing a narrow strip of flake or granular calcium cyanide at right angles to the barriers at intervals of from 1 to 3 rods, the intervals depending on the number of the bugs along the line (Fig. 233). Such an application of cyanide will be effective in killing the bugs for

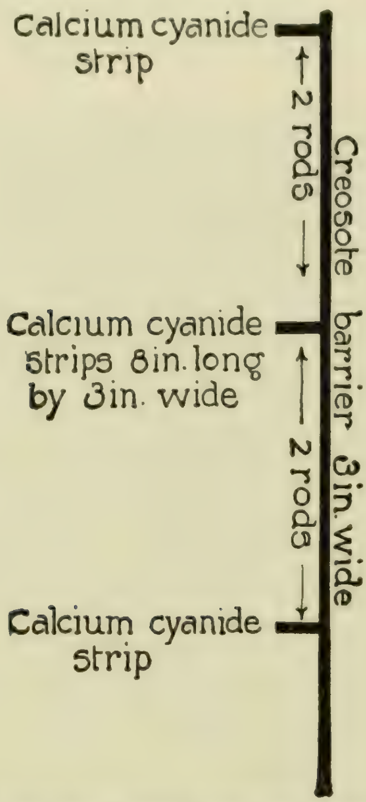


FIG. 233.—Diagram showing method of laying calcium cyanide strips at right angles to a creosote or coal-tar barrier. (*From Ill. Exp. Sta. Bull.* 249.)

from 5 to 10 hours. A tablespoonful of calcium cyanide placed in each posthole at noon, will kill all of the bugs trapped during the afternoon.

References.—Kan. Agr. Exp. Sta. Bull. 191, 1913; *Ill. Agr. Exp. Sta. Bulls.* 243, 1923 and 249, 1924; *U. S. Dept. Agr. Farmers' Bull.* 1498, 1926.

CORN EARWORM[1]

Importance and Type of Injury.—Corn attacked by the corn earworm will show the ears with masses of moist castings at the end, and the kernels, especially about the tip of the ear, eaten down to the cob by large brownish to greenish, striped worms, which are nearly 2 inches long when full-grown (Fig. 234). These worms vary greatly in color from a light green to brown. They are marked with alternating light and dark stripes running lengthwise of the body. The stripes are not always the

[1] *Heliothis obsoleta* Fabricius, Order Lepidoptera, Family Noctuidæ.

same on different individuals. The head is yellow and the legs are dark or nearly black. The skin of the insect is somewhat coarse, and when looked at under a magnifying glass, shows many small, thornlike projections. Usually the injury starts at the tip of the ear. Occasionally the worms enter through the side, or at the butt.

Plants Attacked.—The corn earworm is a very general feeder, attacking many cultivated crops and weeds. It is seriously injurious to the

Fig. 234.—Nearly full-grown larva of corn earworm, feeding in tip of ear of corn. (*From Britton, 21st Rept. State Ent. Conn.*, 1897.)

tomato, tobacco, and cotton, as well as to corn, and has been given the names of tobacco bud worm, tomato fruit worm, and cotton bollworm.

Distribution.—This insect is of worldwide distribution. Its damage is most severe however in the South.

Life History, Appearance, and Habits.—In the southern United States, at least, the insect passes the winter in the form of a brown pupa, which will be found from 2 to 6 inches below the surface of the soil. In the spring, moths (Fig. 235) emerge from these pupæ, and crawl up an exit hole which the larvæ prepared before pupating. The moths have a

wing expanse of about $1\frac{1}{2}$ inches. They vary in color, the average having the front wings of a light grayish brown, marked with dark gray irregular lines and with a dark area near the tip of the wing. The irregular lines often shade into an olive green. The hind wings are white with some dark spots or irregular dark markings.

The moths fly during warm cloudy days, but mainly at dusk of the evening. They feed on the nectar of many flowers, and during the warm evenings deposit their eggs on the plants in which the larvæ feed. Each moth will lay from 500 to as many as 2,500 eggs, the average being probably about 800. These eggs are laid singly, and are of a hemispherical shape with ridges along their sides resembling very much a minute sea urchin. The early generations feed in the curl of young corn plants and on tomatoes, cotton, tobacco, beans, and legumes. Fresh corn silk is one

Fig. 235.—Adult corn earworm with wings spread. Somewhat enlarged. (*From Ill. State Nat. Hist. Sur.*)

of the favorite places for egg laying of the moths of the later generations. The eggs hatch in from 3 to 5 days, and the worms feed at first on the leaves, or bore directly into the corn silk. They feed on the silk and the tip of the ear for about 3 weeks, and on becoming full-grown crawl down the stalk or drop to the ground, into which they burrow and excavate a small, smooth-walled cell, where they pupate, coming out as moths again after another period of 14 to 25 days, although this period may be prolonged during cold weather. The worms do not always remain in the first ear which they entered, but frequently go from one ear to another. They are cannibalistic and usually only one full-grown worm is found in each ear. There are from two to three generations of the insect each season, the number depending on the latitude. While the winter is passed in the pupal stage, it is very doubtful in view of recent work on the life history of this insect if the pupæ ever survive the winter north of about 40° north latitude. The infestations in the northern states are, in all probability, caused by a migration of the adults from points farther south.

Control Measures.—No effective control of the corn earworm in field corn has been devised. Sweet corn can be protected by dusting the silks

with calcium arsenate, or a mixture of calcium arsenate 50 per cent and sulphur 50 per cent. The dust should be applied as soon as the silks appear and repeated three to four times at 3- to 5-day intervals. The worm damage may be reduced in this way from 30 to 50 per cent. This same method has been used in canners' fields with fair success.

The time of planting will have a marked effect on injury by this insect, but will not always be the same in different years; that is, in some years early-planted corn will be injured, while in most years, the latest corn suffers the worst damage. The moths prefer to lay their eggs on fresh corn silk, so that corn which silks before or after the greatest abundance of moths will largely escape infestation. (See also pp. 416, 427 and 490.)

References.—Ky. Agr. Exp. Sta. Bull. 187, 1914; *U. S. Dept. Agr. Farmers' Bull.* 1310, 1923; *Jour. Econ. Entomol.*, Vol. 9, p. 395, 1916 and Vol. 13, p. 242, 1920.

Japanese Beetle[1]

This insect which is described on page 605, under Peach Insects, also has caused very severe damage to corn in areas where it is abundant. Only the adult beetles cause damage, by feeding on the husk, kernels, and silk at the tip of the ear.

There is no practical method for controlling this beetle on corn.

Other Insects Feeding on the Ear

A large number of different species of beetles are sometimes found feeding on the tip of corn ears where the kernels have been exposed by the feeding of the corn earworm, or by birds. These beetles may be regarded as accidental feeders on corn, and practically never attack uninjured ears. The European corn borer described on p. 333 is the most serious insect attacking the ears of corn, in sections where it is abundant.

[1] *Popillia japonica* Newman, Order Coleoptera, Family Scarabæidæ.

CHAPTER XII

INSECTS INJURIOUS TO SMALL GRAINS AND FORAGE GRASSES

FIELD KEY FOR THE IDENTIFICATION OF INSECTS INJURING WHEAT AND OTHER SMALL GRAINS

A. Insects that attack the plant under ground:

1. Young wheat plants killed out in the fall and sometimes in the spring, over irregular areas in the field. Slender, shining, smooth, tough, brown or yellowish-brown larvæ, the largest one to two inches long, with six slender legs, found around the wheat roots. *Wireworms,* page 355.

2. Germinating seed in the ground and young plants eaten by slender, pale-brown or yellowish-brown or nearly black, six-legged larvæ, from $\frac{1}{2}$ to 1 inch in length, the body prominently jointed. Legs and antennæ longer than in true wireworms. Injury occurs in drier parts of wheat belt. *False wireworms,* page 356.

3. Wheat plants, especially in early-sown fields, killed out in the fall over irregular areas in the field. Plants eaten off just above the roots by slender, white, six-legged, brown-headed larvæ which are less than half an inch long and very difficult to find. *Spotted cucumber beetle,* page 358.

4. Roots of plants eaten off in the late spring and sometimes in the fall in early-sown fields, by white, curved-bodied grubs, from $\frac{1}{2}$ to over 1 inch in length, with reddish-brown heads and six long legs. Grubs feed just below the surface of the ground. *White grubs,* page 358.

5. Wheat stalks die at the ground just before harvest. Lower part of stalk hollowed out by white, short, very fat, legless larvæ about $\frac{1}{4}$ inch in length. Stalks sometimes fall. *Billbugs,* page 359.

6. Tender portions of grain plants eaten off just below the ground, or in wet weather above ground, especially in the spring. *Pale-western and other cutworms,* p. 321.

B. Insects that attack the plant above ground:

1. Plants in the fall with stiff, bluish-green leaves; center shoot often missing; or plants dead. Whitish, legless and headless maggots up to $\frac{3}{16}$ inch long; or brown, capsule-like cases of about the same length, behind the lower leaf sheaths. In the spring, many of the straws fall when the heads are beginning to fill; brown seedlike cases about $\frac{1}{8}$ inch long found behind the lower leaf sheaths but not inside the straw. *Hessian fly,* p. 359.

2. Plants in fall having much the appearance of *B*, 1, but with very slender, greenish, footless maggots in the enlarged part at the base of the stem. In the spring, scattered wheat heads are blasted, and turn white just after forming, but do not fall over. The stalk is eaten off inside the leaf sheath at first or second joint below the head, by a pale green, very slender maggot, about $\frac{1}{4}$ inch long. *Wheat-stem maggot,* page 364.

3. Heads of wheat full of very small pink or reddish maggots, $\frac{1}{12}$ inch long or less, that lie among the bracts and feed on the kernels. Kernels shriveled. *Wheat midge,* page 365.

4. Patches of wheat dying in the late spring in parts of the field where the stand is the poorest, or on thin ground. Great numbers of small, red, brown, or black-and-white bugs, the largest only 1/5 inch long, clustered on the lower parts of the stems and on the lower leaves. *Chinch bug*, page 366.

5. Areas of dead and whitened plants appearing in fields in early spring, especially during periods of cool weather. Plants in and about such areas covered with very small, winged and wingless, green, sucking aphids. *Green bug*, page 367.

6. Injury much the same as in *B*, 5, but with the insects more generally distributed over the fields. Later large numbers of the aphids are found in the heads. *English grain aphid*, page 369.

7. Fields of wheat stripped of leaves and the awns of the heads eaten off by large green and dark-green, striped worms up to 2 inches in length, with three pairs of legs and five pairs of prolegs. Worms feed mainly at night and remain at base of plants during the day. *Army worm*, page 370.

8. Part of wheat head eaten off by grayish or greenish-gray worms, with clear-cut brown and yellow stripes on the body, which hide about the base of the plant during the day. Body slenderer and head relatively bigger than in the army worm, and with two straight dark bands over top of head. *Wheat-head army worm*, p. 371.

9. Straw falls as the heads fill, as in *B*, 1, but the inside of the straw is eaten out down to the ground by a pale yellow, wrinkled-bodied larva about 1/2 inch long. *Western wheat-stem sawfly*, page 372.

10. Wheat in early spring with crown of plant eaten out by small, yellowish, maggot-like larva less than 1/4 inch long, with distinct brown jaws, stunting or killing the plant. Later in the spring, after the plant has jointed, it may be injured at the joint by a similar worm eating inside the stem, and the straw weakened so that the head falls. *Wheat strawworm*, page 373.

11. Straw fallen as in *B*, 1, the weakening of the straw caused by small, yellow, legless, brown-jawed larvæ, working in hard, knotty galls, usually just above one of the lower joints. Many bits of the galls and hardened straws coming through the thresher in the grain. *Wheat jointworm*, page 374.

12. Early-sown wheat in the fall sometimes eaten to the ground. In the spring, the heads and leaves are eaten off. *Grasshoppers*, p. 377.

13. Pale-green larvæ up to 2/3 inch long, with distinct heads and at least 10 pairs of legs and prolegs, feeding on the edges of the wheat leaves; often hold the hind part of the body curled against the leaf. *Wheat sawflies*, page 373.

A. INSECTS THAT ATTACK WHEAT

Wireworms[1]

Importance and Type of Injury.—The different species of wireworms doing the greatest amount of injury to wheat are much the same as those which injure corn. So far as is known, all the wheat wireworms (Fig. 236) have a 4-year, or longer, life cycle. The adult beetles (Fig. 237) have the same appearance and character as those attacking corn. For full description of these insects, see Corn Insects, p. 303.

Control Measures.—In general, the control measures for combating these insects given under corn will apply to the species attacking wheat. In the dry-land areas of the West, where wireworms are often particularly destructive, the following control measures have been recommended

[1] *Agriotes mancus* (Say), and others, Order Coleoptera, Family Elateridæ.

by Hyslop and Lane. Disk or harrow sufficiently often, every summer, to maintain a dust mulch, thus keeping down all plant growth and starving out the wireworms; avoid harrowing winter wheat in the spring; and use about 5 pounds extra seed per acre to allow for thinning by

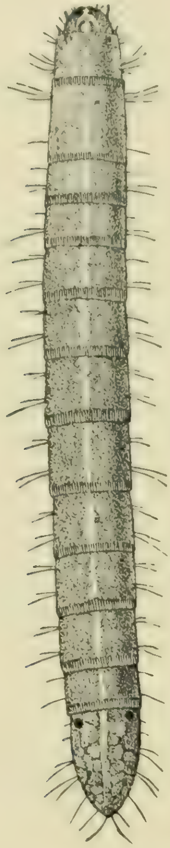


FIG. 236.—The wheat wireworm, larva, five times natural size. (*From Ill. State Nat. Hist. Sur.*)

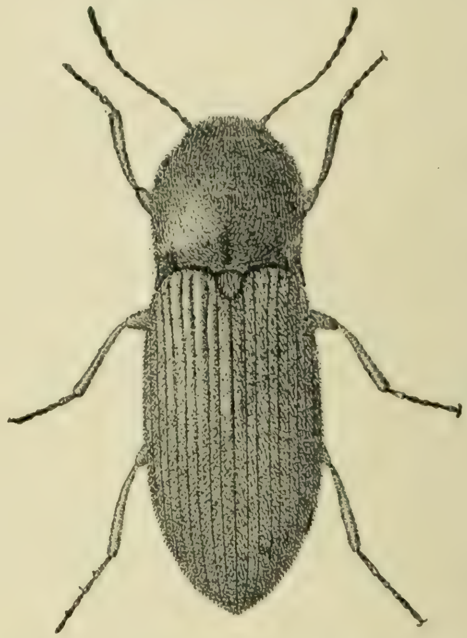


FIG. 237.—Adult of the wheat wireworm, *Agriotes mancus* (Say), seven times natural size. (*From Ill. State Nat. Hist. Sur.*)

wireworms. Firm packing of the seed bed has been found of value in reducing damage to small grains in the Northwest.

References.—*U. S. Dept. Agr. Farmers' Bull.* 725, 1916; *Jour. Econ. Entomol.*, Vol. 18, pp. 90–95, 1925; *Idaho Agr. Exp. Sta. Res. Bull.* 6, 1926.

FALSE WIREWORMS[1]

Importance and Type of Injury.—In the drier wheat-growing sections of the West, wheat is often seriously injured by the larvæ of this and several closely related species of beetles. The germinating seed in the ground and the young plants are fed upon in the fall, and the small plants are often destroyed in the spring. The seed grain in the ground is nibbled and the germ often eaten out. The young wheat plants are

[1] *Eleodes opaca* (Say), *Eleodes suturalis* (Say), and others, Order Coleoptera, Family Tenebrionidæ.

killed over irregular areas in the field, frequently in the vicinity of straw stacks or weed patches. Injury is most severe during dry years.

Plants Attacked.—Native, dry-prairie grass, oats, millet, corn, kafir, alfalfa, beans, sugar beets, garden crops, and other plants. Wheat is much the preferred food plant, most of the other crops being only slightly injured.

Distribution.—States between the Mississippi River and the Pacific Coast, ranging northward into British Columbia and southward to Texas. False wireworms possibly occur in some of the states to the east in small numbers.

Fig. 238.—A false wireworm, *Eleodes letcheri vandykei* Blaisdell, dorsal view of larva, much enlarged. (*From U. S. D. A., Bur. Entom. Bull.* 95, *Part V.*)

Life History, Appearance, and Habits.—These insects pass the winter in the form of partly grown larvæ or as adults. The adults (Fig. 239) are dark to black beetles a little under 1 inch in length. The wing covers of some species are distinctly ridged, others are smooth or granulate and they are grown fast together, making it impossible for the insects to fly. When disturbed, they have a peculiar habit of placing their heads on the ground and elevating the hind part of their bodies as though standing on their heads. The larvæ (Fig. 238) closely resemble wireworms in appearance, but have longer legs and antennæ. Their bodies are brown or yellowish brown in color and very prominently jointed. Some species of larvæ are nearly black. The adult insects become active early in the spring and lay their eggs in the soil, from 10 to as many as 60 being deposited in a place. The larvæ feed on the seeds, roots, and underground parts of the stems of the plants which they attack, and under favorable conditions complete their growth in from 110 to 130 days. They pupate in earthen cells in the soil, the

Fig. 239.—Adults of a false wireworm in characteristic attitudes. Somewhat enlarged. (*From U. S. D. A. Bur. Entom. Bull.* 95, *Part V.*)

pupal period lasting from 10 to 25 days. Most of the damage is caused by the larvæ. The adult beetles are general feeders. They are very

long-lived, in some cases having been known to live for as much as 3 years in the adult stage. A second period of egg laying usually occurs in the late summer or early fall, the larvæ from these eggs hibernating in the soil in a partly grown condition.

Control Measures.—Numerous attempts have been made by different experimenters to find a method of treating wheat that would prevent injury by these insects. While almost every known poison has been used under a number of different conditions, no practical treatment which will poison the larvæ has yet been discovered. The most effective control measure for these insects is rotation of crops that will bring corn or other cultivated crops on the ground for at least 2 years between crops of wheat. General, thorough clean-up of straw and wheat refuse in the fields is also of much help in preventing damage.

References.—*Jour. Agr. Research*, Vol. 22, No. 6, 1921; and Vol. 26, No. 11, 1923; *U. S. Dept. Agr. Bur. Entomol. Bull.* 95, Part V, pp. 73–87, 1912.

Spotted Cucumber Beetle[1]

Importance and Type of Injury.—Wheat is most seriously injured by this insect in the fall. The infested fields show irregular patches of dead plants. If the plants are examined they will be found eaten off below the surface of the ground. Sometimes a slender, yellowish-white larva, a little over ½ inch in length, will be found in the soil about the underground parts of the plants. It is usually very difficult to find these larvæ. The injury is in general confined to, or at least is most severe on, early-sown wheat.

For a full description of this insect, see Corn Insects, page 311.

Control Measures.—Control measures which have been found most effective in lessening damage by this insect on corn will apply equally well for preventing damage to wheat. Perhaps the most effective measure for controlling its injury on wheat is sowing sufficiently late so that the beetles do not lay eggs in the wheat when it first comes up. Wheat sown sufficiently late to avoid damage by the Hessian fly will in general escape injury by the spotted cucumber beetle.

White Grubs[2]

Importance and Type of Injury.—Where wheat is sown early on ground heavily infested with white grubs, the young plants may be damaged in the fall by having their roots eaten off by these insects. The most serious damage to wheat occurs in the spring from grubs feeding on the roots. Heavily infested fields may be nearly destroyed. Feeding usually starts during the latter part of May or the first of June, and continues until wheat harvest. The brown-headed, curved-bodied, six-legged grubs, 1 inch or more in length, will be found just below the surface of the soil about the wheat roots. For a full description of white grubs see Corn Insects, page 306.

Control Measures.—The control measures given for preventing damage by this insect on corn apply equally well to wheat. In addition, most of the fall damage may be prevented by seeding sufficiently late so that the grubs will not feed on the wheat roots before they start their winter migration to below the frost line. Seeding late enough to avoid damage by Hessian fly will prevent most of the fall damage by grubs.

[1] *Diabrotica duodecimpunctata* (Fabricius), Order Coleoptera, Family Chrysomelidæ.

[2] *Phyllophaga* or *Lachnosterna* spp., Order Coleoptera, Family Scarabæidæ.

Wheat is not as severely damaged as corn, but, where possible, should not be planted on ground known to be infested by white grubs.

Billbugs[1]

Wheat infested by billbugs will often show deadened stalks shortly before harvest, or the stalks may fall in much the same manner as where wheat is heavily infested with Hessian fly or jointworm. An examination of the lower parts of the plant will show short, white, curved-bodied, legless grubs with brown heads, feeding in the lower part of the stem and crown of the plant. The burrows made by the insect in the plant are filled with fine, sawdust-like castings. The grubs are rather small, seldom attaining ¼ inch in length. Damage is usually more severe on sod ground, in low-lands, or about the margins of fields. Damage by billbugs to wheat is not usually severe, but has apparently been increasing somewhat during the last few years in the mid-western states. For a full description of billbugs and their control, see Corn Insects, pages 340 and 342.

Hessian Fly[2]

Importance and Type of Injury.—The type of injury caused by the Hessian fly is not conspicuous. Wheat infested in the fall is stunted in growth; the leaves of the plants take on a dark, bluish-green color, become distinctly thickened and stand more erect and stiff than those of uninfested plants. The central growing shoot is often lacking. Small white or greenish-white, shiny, legless and headless maggots about $\frac{3}{16}$ inch in length, or brown, elongated, capsule-like cases (*puparia*), about ⅛ inch long, containing white maggots, will be found behind the sheaths of the lower leaves of the plant, usually below the surface of the ground (Fig. 240, *December to March*). The injury is caused entirely by the larvæ, which withdraw the sap from the lower parts of the stem. Heavily infested plants generally die during the winter. In the early spring, the appearance of the injured plants is much the same as that in the fall. Later in the spring the capsule-like "flaxseeds" will be found behind the leaf sheath above the surface of the ground, sometimes as high as the second or third joints. Infested straws usually break over when the heads begin to fill (Fig. 240, *June*). Heavily infested fields will frequently have 50 to 75 per cent or more of the straws fallen. The yield of infested grains is seriously reduced.

Plants Attacked.—The principal food plants of the Hessian fly are wheat, barley, and rye, and are preferred in about the order named, wheat being by far the favorite food of this insect. It has been taken rarely and in very small numbers on certain species of wild grasses. It has also been taken in very small numbers on emmer and spelt. Eggs have been found on oats, foxtail, and einkorn, but no larvæ have ever been known to develop on these plants, according to McColloch.[3]

[1] *Sphenophorus* spp., Order Coleoptera, Family Curculionidæ.

[2] *Phytophaga destructor* (Say), Order Diptera, Family Cecidomyiidæ.

[3] *Kan. Agr. Exp. Sta. Tech. Bull.* 11, 1923.

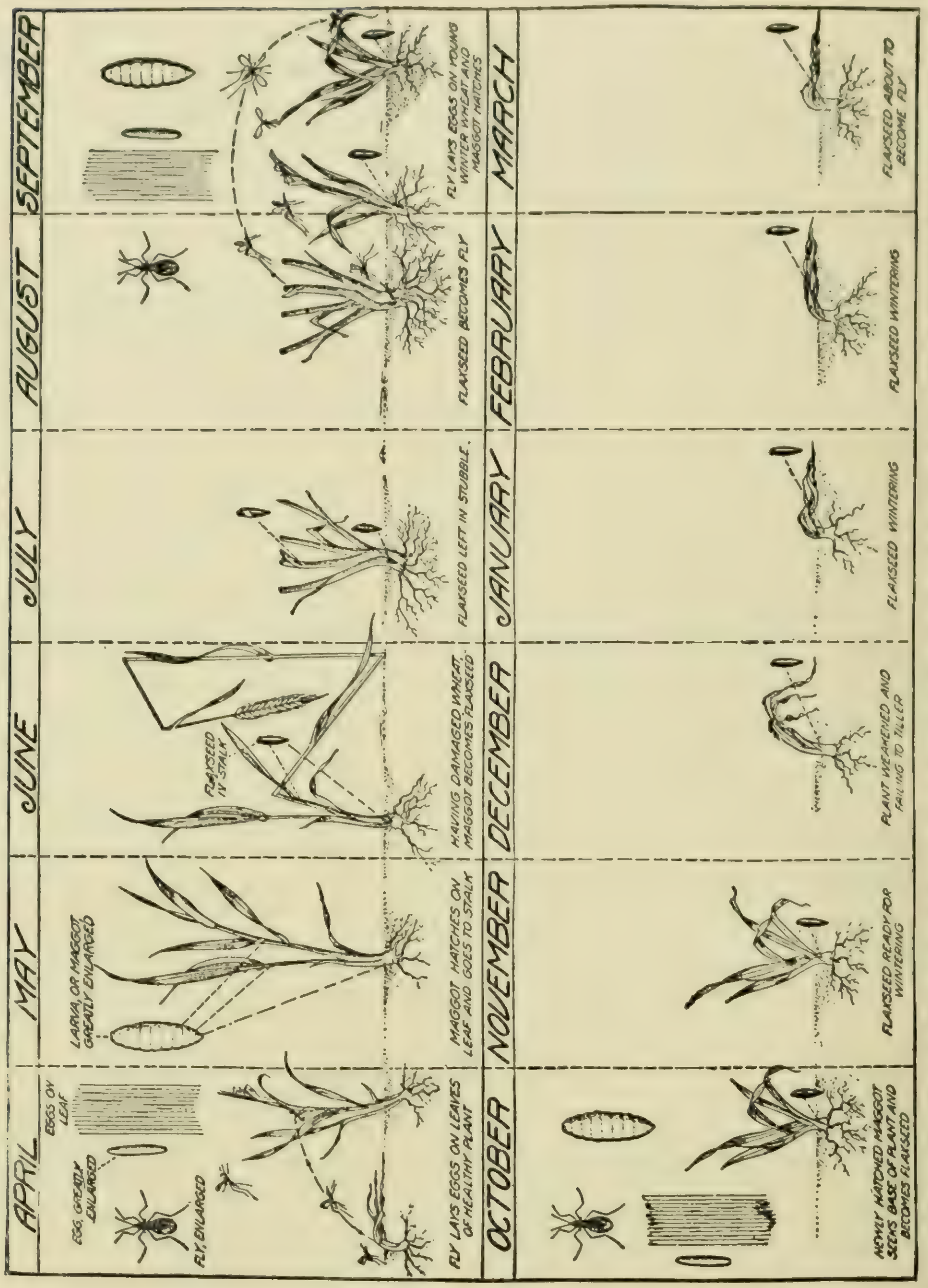


FIG. 240.—Chart showing the relation of the Hessian fly to the wheat plant, each month of the year. (*From* Lochhead, "*Economic Entomology*," *P. Blakiston's Son & Co., after U. S. D. A.*)

Distribution.—The original home of the Hessian fly was probably in the southern Caucausas region of Russia. It was probably introduced into North America in straw bedding used by the Hessian troops during the Revolutionary War, as it was first noted on Long Island about 1779. The insect has now spread to all the principal wheat-growing areas of the world. It is not found in a few of the arid wheat-growing sections in the plains states, but occurs on the Pacific coast.

Life History, Appearance, and Habits.—The Hessian fly passes the winter in the full-grown maggot stage. Occasionally a partly grown maggot will survive. In most cases, however, the maggot is within the brown puparium, or what is commonly called the "flaxseed." These overwintering stages will be found hidden away behind the leaves of the volunteer or early-sown wheat (Fig. 240, *November to March*), between leaf sheath and stem, or in some cases in the stubble of the previous season's crop. The insect is inactive during the winter, all those in the "flaxseed" stage having finished feeding. In the spring, shortly after the wheat plant starts its active period of growth, the maggots change inside the puparia to the pupal stage and in a week or more emerge as small, two-winged flies a little less than ⅛ inch in length. These flies are all of a sooty black color, much smaller than the common house mosquito, and are very frail creatures, never feeding so far as known. During windy weather they remain clinging to the leaves or clustering about the base of the wheat plants. On warm days they fly about over the fields and mate, and the females, whose abdomens are of an orange-red color, lay eggs of the same reddish color in the grooves on the upper sides of the wheat leaves. The eggs (Fig. 240, *April and October*) are very small and can just be seen without the use of a magnifier. They are slender, often laid end to end, and, when viewed through a lens, they have somewhat the appearance of a string of "wieners." They are likely to be overlooked by any but the most careful observers. The adult flies probably never live more than 4 days and most records show that they usually die in 3 days or less. While incapable of flying long distances by their own efforts, they may be carried by a moderate wind for a distance of several miles. Work of Kelley and McColloch in Kansas has shown that the adult Hessian flies will be found fairly abundant at a height of 25 feet above the ground, and that they may occur in considerable numbers at least 2 miles from any of their known food plants. The female flies lay from 250 to 300 eggs, the average number of the fall generation being 285, and for the spring generation slightly less. Many eggs are often deposited on a single plant, as many as 319 having been counted in the fall on one plant. The eggs hatch in from 3 to 10 days, depending on the temperature. The young maggots, which are reddish when they first emerge from the egg, soon turn white. They work their way down the grooves of the leaves as far as they can go behind the leaf sheath, without cutting

through the sheath or the stem. Here they start feeding by rasping on the straw and sucking up the sap which oozes out from the irritated surface. The maggots never enter the straw of the plant as do those of some other insects which are sometimes mistaken for the Hessian fly. With favorable weather, the maggots will become full-grown in about two weeks (Fig. 240, *May, October*). The outer skin then loosens from an inner skin and forms the brown protective case known as the "flax-seed" or puparium. Most of the maggots developing from eggs laid in the spring reach the flaxseed stage some time before the wheat begins to head. Normally, there is one spring generation. Under certain weather conditions, particularly those of an early wet spring, a second or supplementary spring generation may be produced. Flies of the supplementary generation emerge and lay their eggs on the late tillers, normally causing but little injury. Nearly all of the flies will be in the "flaxseed" stage 2 weeks or more before wheat harvest. They remain in this stage in the dry stubble during the summer (Fig. 240, *July, August*) and emerge again as flies as soon as sufficient rain has fallen to cause a growth of volunteer wheat in the fields. During wet seasons, adult flies may begin coming out by the middle of July, and a nearly full summer generation may be produced in volunteer wheat. In normal years, the flies do not start emerging before late summer or early fall and lay their eggs in such volunteer wheat as may be present in the fields, or in early-sown wheat. In central Illinois, emergence starts usually about September 1. If no green wheat, rye, or barley is available, the flies will die without depositing many of their eggs. Emergence ceases on the approach of cold weather. The maggots developing from the fall generation of flies will nearly all become full-grown before the first hard frost or at least before the ground freezes in the fall. Maggots that are less than one-half grown, are likely to be killed by freezing weather.

It will be seen from this description that there are normally two full generations of flies each year, but under exceptionally favorable weather conditions, there may be three, four, or even five.

Control Measures.—The three measures which have been found of most value in preventing damage by this insect are:

1. Sowing sufficiently late in the fall so that the wheat will not come up until after the adult flies have emerged, laid their eggs and died. The accompanying map (Fig. 241) shows the normal safe dates for sowing wheat to escape injury by the Hessian fly and make the largest yields, in some of the North Central States.

2. Keeping down all growth of volunteer wheat in the fields, or about stacks, on which the fall generation of flies might deposit their eggs, and thus carry the insect through until the following spring.

3. Plowing under infested wheat stubble as soon as possible after harvest. The adult Hessian fly is such a weak insect that it cannot

work its way up through the soil, and where wheat stubble is thoroughly plowed under this will prevent the Hessian fly from emerging. This is a most effective control measure but frequently cannot be practiced because wheat is often used as a nurse crop for grasses or clovers which remain on the ground for a year or more after the wheat is harvested.

The proper date of seeding wheat to escape infestation by the fall generation of Hessian fly has now been worked out by the entomologists in the experiment stations of all the principal wheat-growing states. There will be some variation in the time of emergence of the fly during different seasons, as its development is so largely dependent on weather

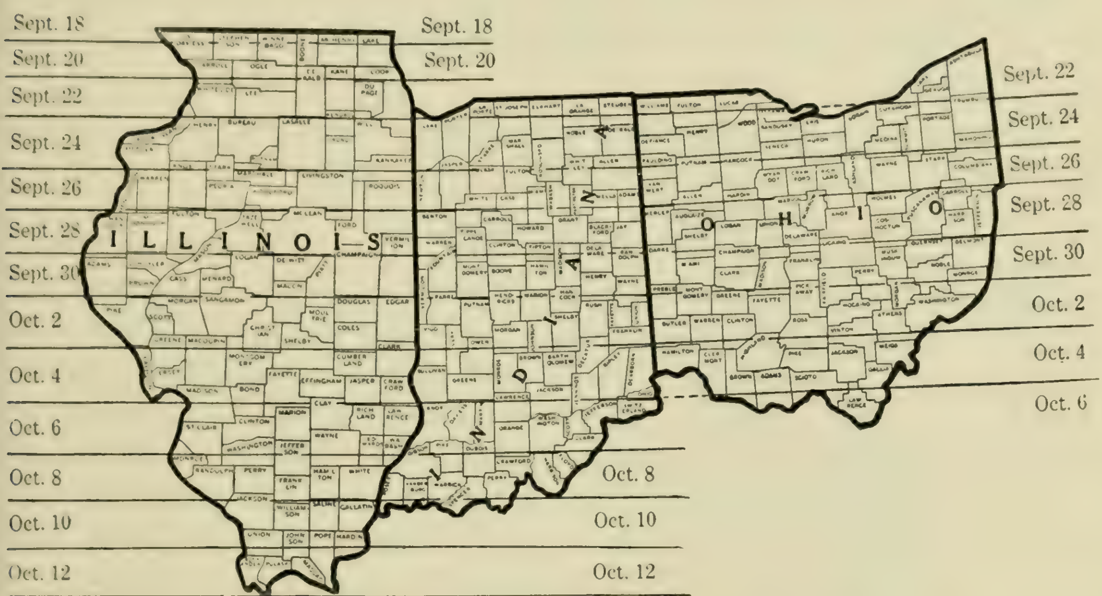


Fig. 241.—Map showing normal safe dates for sowing wheat in several North Central States to escape injury by the Hessian fly.

conditions. However, long-continued experimental seedings in many states have shown that it is nearly always possible to sow late enough to avoid any but a very light infestation by the Hessian fly and still secure a sufficient plant growth to permit the wheat to withstand the cold weather of the winter. The results secured from experimental seedings conducted for 8 years, in Illinois, are summarized on p. 268.

Many experiments have been carried on to develop other methods of control. Those sometimes recommended, but which have been found of practically no value, are: pasturing wheat with cattle or sheep, rolling wheat to crush the maggots or puparia, mowing wheat in the spring after the spring generation of flies has emerged, and early planting of strips of wheat as traps. Under certain conditions, rotation of crops is of some value in preventing injury. Where no grass or clover is sown in the wheat, and the weather is sufficiently dry, summer burning of stubble may be of slight value. In most cases, however, the "flaxseeds"

are sufficiently low in the wheat so that they are not killed by the fire. Some varieties of wheat have been found resistant to Hessian fly, but up to the present time no varieties have been found sufficiently resistant to attacks of this insect, and having other desirable qualities, to warrant recommending them generally in any of the large wheat-growing areas. Maintaining the wheat ground in a good state of fertility is of considerable value, as a wheat plant on rich ground will overcome the attack of one or two maggots of the Hessian fly and still produce a fairly good yield, whereas on poor ground such a plant would be killed. Where late seeding is practiced, the seed bed should be put in the best condition possible so that a vigorous growing plant may be obtained. No method has yet been developed for controlling Hessian fly by direct application of insecticides.

References.—Kan. Agr. Exp. Sta. Tech. Bull. 11, 1923; *Ohio Agr. Exp. Sta. Bull.* 177, 1906; *Jour. Agr. Research,* Vol. 12, pp. 519–527, 1918.

Wheat-stem Maggot[1]

Importance and Type of Injury.—Wheat attacked by this insect in the fall of the year appears much the same as that infested by the Hessian fly, the plants taking on a darker appearance and remaining stunted, with stiff, somewhat thickened leaves. An examination of these plants will reveal slender, pale-green maggots (Fig. 242, *B*) working inside the lower part of the stem or crown of the plant. These maggots are about ¼ inch long.

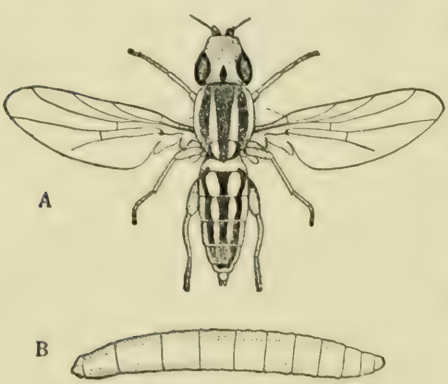


FIG. 242.—*A*, adult of the wheat stem maggot, *Meromyza americana* Fitch, six times natural size. *B*, larva of the wheat-stem maggot, six times natural size. (*From Ill. State Nat. Hist. Sur.*)

The summer type of injury differs from that of the winter. The first indication of the presence of the insects is usually the dying out and whitening of the wheat heads and upper parts of the straw shortly after the head begins to fill while the lower stem and leaves are still green. The maggots will be found at this time of the year inside the straw just above the last or next to the last joint. The whitened heads are very conspicuous in the green fields of wheat often giving an exaggerated idea of the importance of the insect. Its injury rarely amounts to 1 or 2 per cent, but occasionally may be much higher.

Food Plants.—The principal food plants among the cultivated crops are wheat, rye, barley, and oats. It also feeds on blue grass, timothy, and a number of the wild grasses.

[1] *Meromyza americana* Fitch, Order Diptera, Family Oscinidæ.

Distribution.—The insect is a native species, occurring over practically the entire United States, in Mexico, and in the principal agricultural regions of Canada.

Life History, Appearance, and Habits.—The insect, so far as known, passes the winter only in the larval stage, the maggot being hidden away inside the lower parts of the stems of the wheat or the other plants on which it feeds. In the spring these larvæ change inside a green puparium to the pupal stage and emerge shortly afterward as yellowish-white flies, about $\frac{1}{5}$ inch long, with three conspicuous black stripes on the thorax and abdomen, and conspicuous bright-green eyes (Fig. 242, *A*). The females, after mating, deposit their eggs on the leaves or stems of wheat and grasses on which the larvæ feed. The young maggots crawl down behind the leaf sheaths to the tender soft part of the stems and tunnel into them, in the case of wheat feeding along the stem for a distance of 2 or 3 inches. The injured stem is partly severed and the head turns white and dies. When the larva becomes full-grown, the outer skin loosens from an inner skin and forms a pale-green slender puparium in which the maggot changes to the pupal stage, and later to the adult stage. These adults emerge about midsummer and lay their eggs on wild grasses or volunteer grain. The larvæ of this summer generation become full-grown by the last of August or during September and transform to adults that emerge and lay eggs for the fall generation which develops on winter wheat as above described.

Control Measures.—No practical method of controlling this insect has yet been developed. The date of seeding has some effect on the amount of injury in certain years, but late seeding cannot be depended upon to prevent injury. Where the insect has so many food plants other than wheat, we are practically dependent upon its natural enemies to hold it in check. Destruction of straw that is heavily infested by these maggots, or the baling and selling of straw off the farm, if done soon after wheat harvest, will help somewhat in reducing the number of insects.

References.—*U. S. Dept. Agr. Bur. Entomol. Bull.* 42, p. 43, 1903; *U. S. Dept. Agr. Dept. Bull.* 1137, 1923.

Other Maggots Infesting the Stems of Wheat

There are several other maggots closely related to the wheat-stem maggot which feed on and sometimes damage wheat. They are seldom of much importance and so far as known have somewhat the same life histories as that of the wheat-stem maggot. No special methods of control have been developed for these insects.

Wheat Midge[1]

Importance and Type of Injury.—Injury by this insect is confined entirely to the heads of wheat, and occurs after they begin to fill. Infested heads will show shrunken

[1] *Thecodiplosis mosellana* Gehin, Order Diptera, Family Cecidomyiidæ.

kernels at the time of harvest. In cases where the infestation is very heavy, many small, orange-yellow maggots, up to 1/12 inch long, will be clustered around the bracts of the wheat head, sometimes so thick as to give the whole head a reddish appearance. Heavily infested fields may have the grain so damaged that it is suitable only for chicken feed, or is almost entirely destroyed.

Plants Attacked.—Wheat, rye, barley, and oats.

Distribution.—The wheat midge is a European insect which was probably introduced into America some time about 1815 to 1820, in the Province of Quebec. It has spread practically throughout the wheat-growing belt of North America east of the Rocky Mountains, and into British Columbia and Washington. It is more serious in the northern part of its range.

Life History, Appearance, and Habits.—The winter is passed in the pupal stage inside a very small brown puparium just below the surface of the ground. The adult flies are very small, orange-yellow gnats, only about 1/10 inch long. They emerge from the overwintering puparia during the latter part of May and June, and the females deposit their eggs about the green kernels of wheat and in the bracts of the wheat heads. These hatch into tiny reddish maggots that feed on the growing wheat grains, and usually become full-grown shortly before wheat harvest, when they drop to the ground, and, working their way below the surface, change to the puparia. There is but one generation a year.

Control Measures.—The best control measures are to plow under the stubble after threshing and burn the litter where the separator has stood. Rotation of crops also is of some value, as the adult wheat midge is a very frail insect and can fly only comparatively short distances.

References.—*Rept. N. Y. State Entomol.*, 1923; *Purdue Agr. Exp. Sta. Circ.* 82, 1918.

Chinch Bug[1]

Importance and Type of Injury.—Wheat fields infested with the chinch bug show a deadening and drying out of the plants early in the spring. As the wheat begins to head, deadened areas will appear over the fields. Usually these areas are in the spots where the soil is the poorest or where the stand of wheat has been partly killed out by the winter or by heavy rains early in the spring. Thus in dry years these spots will usually appear in the higher parts of the field, while following wet springs they will usually be noticed in the low, wet spots. The chinch bug is a sun-loving insect, and always seeks the spots in the field where the crop is thin. Numerous, red, dark-brown, gray, or black-and-white bugs, from very small up to 1/5 inch long, will be found in hoards about the bases of plants in and around the margins of the injured area where they are sucking the sap from the growing crop. For full description of the chinch bug, see Corn Insects, page 344.

Control Measures.—No effective practical control has been developed which will rid infested wheat fields of the chinch bug. The best measure for reducing damage to wheat in years when chinch bugs are abundant and in areas where this can be practiced, is a general burning out of the bugs in their winter quarters. The sowing of wheat on fertile soil, which will promote a heavy growth, is of value, as chinch bugs avoid shade

[1] *Blissus leucopterus* (Say), Order Hemiptera, Family Lygæidæ.

and dampness and will not be found in large numbers in fields having good stands of wheat with a strong uniform growth. Sowing clovers in wheat will also help to keep down the number of bugs in the field, as the growth of these plants shades the ground. Very few chinch bugs spend the winter in wheat stubble, so that burning over the infested stubble during the latter part of the summer is practically of no value for the control of these pests.

References.—U. S. Dept. Agr. Farmers' Bull. 1498, 1926; *Kan. Agr. Exp. Sta. Bull.* 191, 1913; *Ill. Agr. Exp. Sta. Circ.* 268, 1923; and *Bulls.* 243, 1923 and 249, 1924.

Green Bug[1]

Importance and Type of Injury.—Wheat or other small-grain fields infested by the green bug usually show small deadened areas appearing in the field during the late winter or early spring. An examination of such areas will show the plants swarming with numbers of tiny green aphids or plant lice (Fig. 243, *A*), which are sucking the sap. During periods of spring weather, favorable to the aphids, these deadened spots may spread rapidly and the entire field be killed out.

Plants Attacked.—The green bug feeds on all the small grains and many of the wild and cultivated grasses. It has also been found on rice, corn, sorghum, and several other cultivated plants.

Distribution.—The insect is of European origin and was first recorded in the United States in 1882 in Virginia. It has now spread so it is generally distributed over practically all of the United States, its range extending on the north into Canada. The green bug is not common in the New England states. Its greatest damage has been done in the large grain-growing states west of the Mississippi, including Oklahoma, Texas, Kansas, and Nebraska.

Life History, Appearance, and Habits.—In the southern states this insect passes the winter in the active nymphal and adult stages, feeding on the stems of plants and giving birth to living young during the warmer periods of weather. In the more northern states the winter is passed in the form of black, shiny eggs, deposited on the leaves of plants on which the insect feeds. These eggs hatch during the winter or early spring, producing numbers of pale green, wingless female insects, about 1/16 inch in length when full-grown, and having a dark green stripe down the back (Fig. 243, *A*). In from 7 to 18 days after hatching, these females begin giving birth to living young. These may become either winged or wingless. The winged individuals differ slightly in appearance from those hatching from the winter eggs, being slightly larger and with filmy wings having an expanse of about 1/4 inch. The head is brownish yellow and there are blackish lobes on the back of the thorax. In about 15 days these

[1] *Toxoptera graminum* Rondani, Order Homoptera, Family Aphididæ.

females, in turn, begin giving birth to living young, and the insects continue thus, generation following generation. Each female begins reproducing when from 7 to 18 days old and continues to reproduce for about 20 to 30 days, giving birth during this time to an average of from 50 to 60 young. It will be seen from these figures, that the rate of reproduction is enormous and almost beyond comprehension. If unattacked by natural enemies, in the course of a single season the mass of aphids which could be produced would be so great as to destroy all vegetation upon which they could feed. On the approach of cold weather, the female aphids give rise to winged males and females. These mate, and the

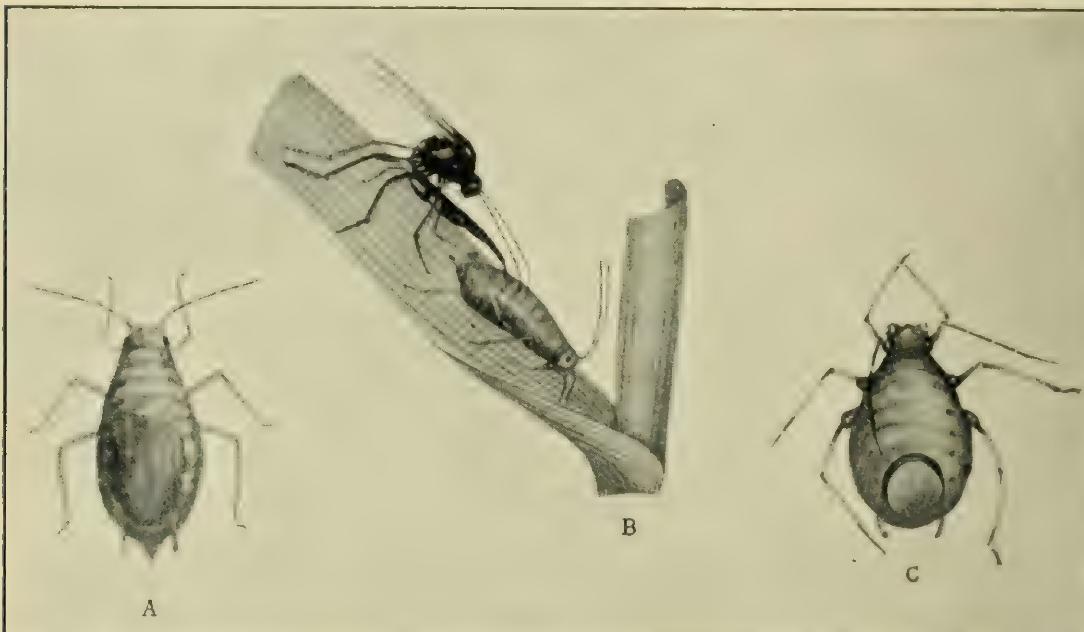


FIG. 243.—The green bug. *A*, a parasitized specimen, the larva of the parasite showing through its body wall. *B*, a female of the parasite, *Lysiphlebus testaceipes* Cresson, ovipositing in a green bug. *C*, the dead "shell" of a green bug showing the circular hole through which an adult parasite has emerged. All much enlarged; actual size about the same as the letters in this figure. (*Modified from Kans. Univ. Bull., Vol.* 9, *No.* 2.)

mated females produce eggs, in which stage the insect passes the winter in the colder parts of the country. A single female may at times both lay eggs and give birth to living young. There are from five to fourteen generations each season, all except the last being composed entirely of females.

Control Measures.—The abundance of this insect and resultant injury are very largely dependent on weather conditions, and can be but little influenced by man. No serious outbreak of the green bug has occurred except when the preceding summer was comparatively cool and moist. The worst outbreaks have always occurred in seasons of mild winters followed by cool, late springs. The reason for this is that the green bug will start reproducing at temperatures a little above 40° F., and can reproduce at a fairly rapid rate at temperatures between 55 and 65° F.

It is preyed upon by a number of insect enemies, but particularly by a little wasp[1] (Fig. 243, *B*). This tiny wasp stings the aphids and deposits its eggs within their bodies. These eggs hatch into little maggots which eat out the body substance of the aphid, and finally emerge as adults, through a hole cut in the back of the aphid (Fig. 243, *C*). These wasps are practically always present in areas where the green bug is abundant. When the temperature is below 65° F., the wasp will reproduce very slowly or hardly at all. Long periods of cool, wet weather thus permit the green bug to increase in enormous numbers while its most effective natural enemy can increase only very slowly. This relationship between the two insects, and the effect of the weather upon them, is apparently responsible for the abundance of the aphids during the years of mild winters and cool springs. In normal years the wasp-like parasites reproduce at a sufficiently rapid rate to hold down excessive abundance of the aphids.

Of the control measures that can be exercised by man, the most effective is the destruction of volunteer grain, especially oats. The heavy masses of volunteer oats in the spring, with their thick growth, are particularly favorable to the aphids and they will often start in fields having an abundance of such volunteer grain and with favorable weather spread from these centers over adjoining areas. It has been suggested that the green bug can be killed by covering the first brown spots in the field with straw and burning the straw. This method, however, is not practical under most conditions.

References.—Bull. Univ. Kan., Vol. 9, No. 2, 1909; *U. S. Dept. Agr. Farmers' Bull.* 1217, 1921; *U. S. Dept. Agr. Bur. Entomol. Bull.* 110, 1912.

English Grain Aphid[2]

Importance and Type of Injury.—Grain infested by the English grain aphid will show somewhat the same appearance as that infested by the green bug. However, the infestation is not usually confined to small spots in the field. After the wheat or small grain begins to head, very large numbers of these aphids will often be found clustered in the bracts of the wheat heads, or in the heads of other grain (Figs. 244 and 245). Their feeding may shrivel the growing wheat kernels and in the early spring cause the death of the wheat plants.

Plants Attacked.—This insect feeds on all of the small grains and many of the wild and cultivated grasses. It has been found in small numbers on corn, but is not an important pest of this plant.

Distribution.—The English grain louse is generally distributed throughout the United States and southern Canada wherever small grains are grown.

Life History, Appearance, and Habits—This insect passes the winter mainly in the fully or partly grown stages. A few individuals go through the winter in the egg stage. It will be found in the heaviest growth of grain and especially in clumps of volunteer oats, rye, or wheat that has made a rank growth. The overwintering forms

[1] *Lysiphlebus testaceipes* Cresson, Order Hymenoptera, Family Braconidæ.

[2] *Macrosiphum granarium* (Kirby), Order Homoptera, Family Aphididæ.

are all females, and as the weather becomes warm in the spring, they begin giving birth to living young which may become winged or wingless. They feed during the early spring on the growing grains, sucking the sap from the leaves and stems. As the heads begin to form, many of the aphids will gather in the heads, causing shriveling and shrinking of the newly formed grain. After the harvest of small grains the insects migrate to wild or cultivated grasses where they spend the summer. In the fall, after the winter grains are planted, they go back to them, or, as above stated, gather in large numbers in clumps of volunteer grain. The males appear during the fall and early winter and mate with the true females, which lay eggs on the grains where they have been feeding. Only a comparatively small number of eggs are laid, the average number being about eight. The wingless females are of a pale-green color with long black antennæ and have a long black cornicle extending backwards from each side of the abdomen. The winged individuals are about the same size and of the same general color. The lobes on the thorax, however, are brown or blackish. The wing expanse is a little over ¼ inch.

FIG. 244.—A head of wheat infested by the English grain aphid, *Macrosiphum granarium* (Kirby). (*From Ill. State Nat. Hist. Sur.*)

FIG. 245.—The English grain aphid clustered about the bracts of a wheat head, enlarged about three and one-half times. (*From Ill. State Nat. Hist. Sur.*)

Control Measures.—As is the case with the green bug, we are largely dependent upon natural enemies for the control of this insect. It is usually held in check by several parasites, and by lady beetles, and other aphid eaters. During cool springs, it may become sufficiently abundant to cause damage. Destruction of volunteer grain in the fall is of value in controlling this species.

Reference.—*Jour. Agr. Research*, Vol. 7, pp. 463–480, 1916.

ARMY WORM[1]

Importance and Type of Injury. Army worms are most apt to be destructive to wheat and other small grains when wet weather has caused a rank growth in the fields. The female moths lay their eggs in large numbers among the rank or lodged grain in the fields and the worms hatching from these eggs may suddenly appear in such numbers as completely to strip the leaves from the grain and then crawl out into other near-by fields. For full description of this insect, see Corn Insects, page 318.

[1] *Cirphis unipuncta* Haworth, Order Lepidoptera, Family Noctuidæ.

Control Measures.—In wheat and other small grain fields, the only method of controlling the army worm is to watch the fields closely in years when the moths are known to be abundant and if the worms are found in the fields, apply poison bran at once (see p. 319).

Wheat-head Army Worm[1]

Importance and Type of Injury.—Wheat, shortly after it is headed, may have parts of the heads eaten off at night by grayish or greenish-gray, white-striped worms which

Fig. 246.—The wheat head army worm, nearly full-grown larvæ feeding on heads of wheat, about natural size. The upper left-hand worm shows the egg of a parasite on its back. (*From Ill. State Nat. Hist. Sur.*)

remain hidden around the base of the plant during the day (Fig. 246). These are the larvæ of the wheat-head army worm.

Plants Attacked.—The insects feed mainly on timothy and wheat. They also attack some other grains and grasses.

Distribution.—General throughout the eastern United States and Canada and westward into Colorado, New Mexico and Arizona. More abundant in the northern states.

[1] *Neleucania albilinea* Hübner, Order Lepidoptera, Family Noctuidæ.

Life History, Appearance, and Habits.—The insect passes the winter in the pupal stage in the ground and has practically the same life history as the true army worm, there being from two to three generations each season.

Control Measures.—The control measures for this insect are the same as those for the true army worm. If the insects become abundant in fields of wheat, they can be readily poisoned by using the same bait as recommended for the control of the army worm.

References.—*Jour. Econ. Entomol.* Vol. 4, p. 176, 1911; *Iowa Agr. Exp. Sta. Bull.* 122, 1911.

Western Wheat-stem Sawfly[1]

Importance and Type of Injury.—Wheat infested by this sawfly will show fallen straw in much the same manner as fields infested by Hessian fly or jointworm. Examination of the straw will show the inside filled with fine sawdust-like cuttings, among which will be found a wrinkled-bodied, nearly legless, brown-headed larva about ½ inch long, of a pale yellow color.

Plants Attacked.—Wheat, spring rye, barley, timothy, quack grass, and some of the native grasses.

Distribution.—The insect is native to North America and is most destructive in the northern wheat-growing states west of the Mississippi River.

Life History, Appearance, and Habits.—The winter is passed as a mature larva in the base of the wheat straw near the surface of the soil. In the spring, the larva transforms to a pupa inside the wheat straw and the adult emerges during June. The adult is wasp-like in appearance, black, with yellow rings on the abdominal segments. The females lay their eggs by thrusting them into the plant tissues on the upper parts of the wheat stem. The larva feeds within the stem, boring down through the joints, and, by late summer, has reached the lower parts of the plant close to the surface of the ground. Here it remains during the winter.

Control Measures.—Plowing under infested stubble in the fall, making sure that it is thoroughly turned under to a depth of 5 or 6 inches is the best method of control. The overwintering larvæ remain so close to the surface of the soil that it is impossible to kill many of them by burning. Cutting grains as early as possible without seriously affecting the yield or grade of wheat does much to reduce damage by this insect. Rotation of crops which will put some immune crops, as corn, winter rye, alfalfa, or sweet clover, on the wheat-stubble land, is also a help in combatting this insect.

References.—*U. S. Dept. Agr. Dept. Bull.* 841, 1920; *U. S. Dept. Agr. Bur. Entomol. Circ.* 117, 1910; *Dom. Canada Dept. Agr. Pamphlet* 6, n. s., 1922.

[1] *Cephus cinctus* Norton, Order Hymenoptera, Family Cephidæ.

Sawflies That Feed on the Wheat Leaves[1]

There are several species of sawflies that feed on the leaves of wheat. In all of these the larvæ may be recognized by their wrinkled bodies, in most cases of a pale-green color, and by the number of abdominal prolegs of which there are always six pairs or more. They occur throughout the wheat-growing areas of the country, but are seldom if ever of economic importance. Occasionally, some of these species will become abundant enough partially to strip the plants of leaves, but, as this stripping does not occur until the wheat head is partially filled, it has but little effect on the yield of the grain. They are, in general, heavily parasitized, and no special control measures are necessary to keep down their numbers.

Wheat Strawworm[2]

Importance and Type of Injury.—Injury by this insect is of two distinct kinds: that caused by the first generation larvæ in young plants in early spring, and the later injury by the second generation, in the maturing straw. In the spring, plants attacked by the wheat strawworm show a stunted appearance; the crown of the plant is usually eaten out, including the developing head, and the plant killed or so injured that no head is produced. The later injury, after the plant has started to form joints, has a somewhat stunting effect, weakening the straw, although a head may be produced.

Plants Attacked.—Wheat.

Distribution.—The insect is generally distributed in the wheat-growing regions west of the Mississippi River, and is found in small numbers, but is rarely destructive, in the states east of the Mississippi River.

Life History, Appearance, and Habits.—The insect passes the winter in the pupal stage in the stubble. In the early spring the adult insects gnaw small round holes in the straw, through which they emerge. Usually emergence takes place during April or, in early springs, in March. These adults from the overwintering pupæ are wingless and about 1/6 inch in length. The general color of most of the insects is brownish. They have much the appearance of ants. Upon examination with a lens their bodies will be seen to be quite hairy. They deposit their eggs in the stem walls at the base of the young wheat plants a little above the ground. The larvæ, on hatching, work their way into the stem, eating off the developing head and preventing the formation of any tillers on the plant. The larvæ, which are yellowish, legless, with small heads, and only about 1/5 inch long, become full-grown the latter part of April or first of May. They pupate within the plant and emerge as adults the latter part of May. These adults (Fig. 247) are larger than the early spring adults, less hairy, somewhat black in color, and are practically all winged. The females deposit their eggs inside the straw during the late spring, usually

[1] *Dolerus arvensis* Say, *Dolerus collaris* Say, and *Pachynematus extensicornis* (Norton), Order Hymenoptera, Family Tenthredinidæ.

[2] *Harmolita grandis* Riley, Order Hymenoptera, Family Chalcididæ.

about the time the wheat is heading. In general, only one egg is laid in a wheat stem. The larva feeds within the stem and remains in this stage during the summer, either in the cut straw, or, if it was working in the lower part of the stem, in the standing stubble. They change to the pupal stage in midfall and pass the winter in this stage. There are thus two generations of the insect a year, the adult females of the two generations being strikingly different in size and appearance.

Control Measures.—As the majority of the adults of the spring generation, which is by far the most destructive, are wingless, and those

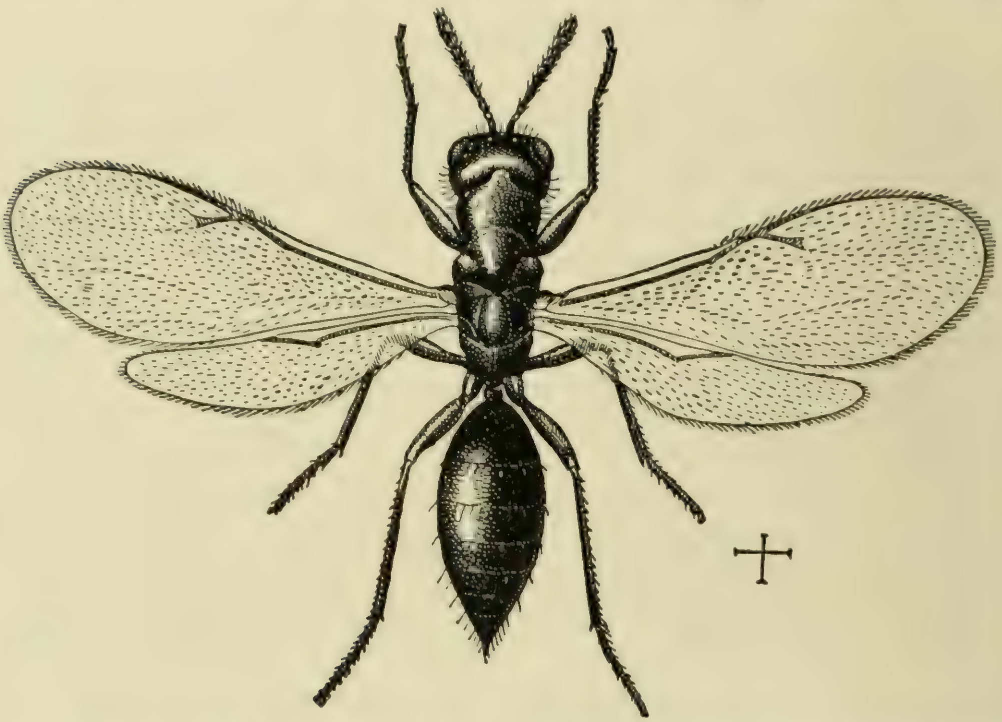


FIG. 247.—Adult female of the summer generation of wheat strawworm, greatly enlarged. Line shows natural size. (*From U. S. D. A. Dept. Bull.* 808.)

of the summer brood are not strong fliers, one of the best methods of controlling this insect is by rotation of crops. It is impossible for the spring brood to crawl any great distance from the infested stubble. Baling and shipping infested straw to cities or towns, is also a help in reducing the numbers of this pest. Many of the overwintering pupæ may be destroyed where the stubble can be closely burned.

References.—U. S. Dept. Agr. Dept. Bull. 808, 1920; *U. S. Dept. Agr. Farmers' Bull.* 1323, 1923; *U. S. Dept. Agr. Dept. Bull.* 1137, 1923.

WHEAT JOINTWORM[1]

Importance and Type of Injury.—In the large wheat-growing areas east of the Mississippi, the wheat jointworm is probably second in importance only to the Hessian fly as an insect pest of wheat. Infested

[1] *Harmolita tritici* Fitch, Order Hymenoptera, Family Chalcididæ.

fields just before harvest time will show many of the straws broken off and bent over in a manner similar to fields infested by the Hessian fly. An examination of the fallen straws will show numerous, hard, gall-like swellings filling the entire straw, usually just above the joints (Fig. 248). Inside these swellings, in oval cavities, are small, yellowish maggots about $\frac{1}{7}$ to $\frac{1}{6}$ inch in length. When infested fields are threshed, many small bits of broken straw containing these galls will come through into the grain or be thrown out in large numbers around the separator.

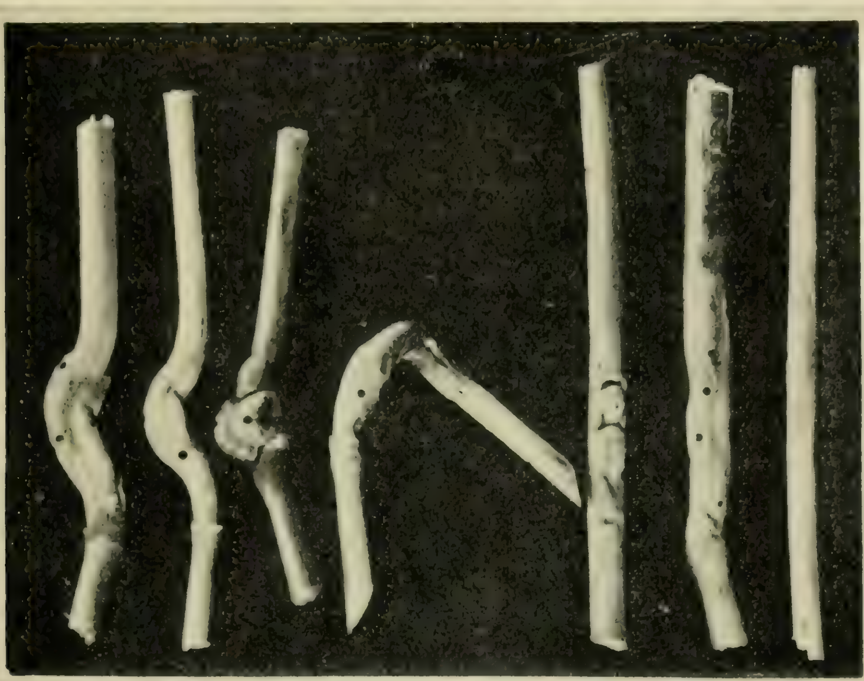


FIG. 248.—Characteristic galls in wheat straws caused by the wheat jointworm, showing exit holes of adults or parasites; about natural size. (*From U. S. D. A. Dept. Bull.* 808.)

Plants Attacked.—Wheat is the only host known in the East but it is reported from grass in California.

Distribution.—The wheat jointworm is a native insect, and is generally distributed in the states east of the Mississippi. Its range extends, however, into some of the states west of the Mississippi, but it has caused little damage in this area except in Missouri.

Life History, Appearance, and Habits.—The winter is passed in the gall-like, hardened swellings inside the wheat straw, the insect being in the pupal or larval stage, mainly in the former. Those that have passed the winter in the larval stage change to pupæ early in the spring, and all emerge as adults about the time the active growth period of the wheat starts, or the plants are beginning to form joints. The adult insects are about $\frac{1}{10}$ to $\frac{1}{8}$ inch in length, and are jet black with the exception of the joints of the legs and two spots on the shoulders which are yellow. The females after mating insert their eggs just above the wheat joints and inside the straw (Fig. 249). They drill a tiny hole

into the wall of the straw by means of a stiff, hair-like ovipositor attached to the underside of the abdomen. Usually a number of eggs are laid in one place, sometimes as many as 25. Occasionally, only one egg will be deposited in a plant. The larvæ feed within the walls of the straw and the irritation set up by this feeding causes the straw to thicken, each larva being separated from the others in a little cavity of its own. Often the swellings around the larvæ cause the straw to twist or the formation of the galls makes the straw so brittle that it is broken over in the field. The larvæ complete their growth about the time the wheat matures, but remain in the larval condition inside the straw until fall, when most of them pupate. The height of the jointworms inside the straw will vary in different seasons. Sometimes the galls will be just above the first

FIG. 249.—Adult female jointworm with her ovipositor thrust through the leaf sheath into the straw. Enlarged about six times. (*From Ohio Agr. Exp. Sta. Bull.* 226.)

joint, within 8 or 10 inches of the surface of the ground, and at other times the galls may be as high as the third joint, and will, therefore, be cut off with the straw when the wheat is harvested. The variation in the height of the galls is due to the difference in the development of the plant at the time the eggs are deposited, the females tending to lay their eggs in the uppermost parts of the plant.

Control Measures.—If wheat stubble can be thoroughly burned, practically all of the overwintering jointworms remaining in the stubble may be killed. Plowing the infested stubble under shortly after harvest, being sure that all stubble is turned under to a depth of 5 or 6 inches, is a good control measure. In seasons when the larvæ are well up in the straw, it is possible by cutting the wheat low to remove nearly all of the insects in the straw. Such straw may then be baled and sold for use in cities or, if it cannot be disposed of in this way, it should be burned.

Rotation of crops, putting any other crop than wheat on the land, also may be of some help in reducing the numbers of this insect. In ordinary years, most of the infestation originates from not burning, or not plowing under, the stubble of the previous season, so that every effort should be made to burn or turn under such stubble before the time of emergence of the adults in the spring.

References.—*U. S. Dept. Agr. Farmers' Bull.* 1006, 1918; *Ohio Agr. Exp. Sta. Bull.* 226, 1911; *U. S. Dept. Agr. Dept. Bull.* 808, 1920.

Grasshoppers

Grasshoppers, when abundant, especially in the spring-wheat-growing sections, frequently cause severe injury to the wheat by eating off the bracts or sometimes cutting off newly formed heads. As a rule, severe damage by grasshoppers to wheat occurs only in the western states. Early-sown wheat is sometimes killed by grasshoppers' feeding upon it in the fall. Grasshoppers may be controlled on wheat by the methods given for controlling these insects on corn.

For a full description of grasshoppers, see Corn Insects, page 327.

B. INSECTS THAT ATTACK RYE

Rye is not so subject to injury by insects as is wheat. It is fed upon to a limited extent by the Hessian fly, but the injury to rye is not nearly so severe. In one case where comparisons could be made of the number of eggs laid on wheat and rye, in adjoining strips alternating through a field, it was found that only about one-sixth as many eggs of the Hessian fly were laid on the rye as on the wheat. The Hessian-fly maggots seem to have greater difficulty in developing on rye than on wheat. The same control measures apply as on wheat.

Rye is especially subject to attack by chinch bugs, unless the stand is heavy so that the bugs are repelled by the shady condition. It is also subject to the attack of the sawflies and jointworm. None of these insects are serious pests on rye.

C. INSECTS THAT ATTACK OATS

Oats are comparatively free from serious insect injury. They suffer more severely perhaps than other small grains during outbreaks of army worms. Oats are never attacked by the Hessian fly. In most years, oats have not made sufficient growth to be attractive to chinch bugs when they leave their winter quarters, and, therefore, escape injury, except such as may occur from migrating bugs at wheat harvest. In years when the English grain louse is abundant, it sometimes severely injures oats.

D. INSECTS THAT ATTACK BARLEY

Barley is somewhat more subject to insect injury than oats. It is one of the favorite foods of the chinch bug, and fields of barley growing

in areas generally infested by the chinch bug are usually more severely injured and contain greater numbers of these insects than adjoining or near-by fields of rye, oats, or wheat. Barley is also fed upon to some extent by the Hessian fly, although it does not damage this crop to nearly the extent that it does wheat. Army worms, grasshoppers, stem maggots and aphids also attack barley. For the control of these insects, see the discussions under Wheat.

E. INSECTS THAT ATTACK TIMOTHY, BLUE GRASS, RED TOP, AND OTHER GRASSES

Nearly all of the insects that attack this group of crops attack also corn, and have been fully treated as pests of that crop. A few of these insects may be controlled on grasses by special measures not applicable to the pests on corn. White grubs, wireworms, billbugs, and cutworms are all pests of grasses, attacking the roots underground or, in the case of timothy, the bulb of the lower part of the stalk. They may be controlled by rotating grass lands, where this can be done; or by pasturing grass lands with hogs in the case of white grubs. And they may be reduced to some extent by sowing pastures and other permanent grass lands with mixtures of grasses and legumes.

Grasses, above ground, are particularly liable to attack by grasshoppers, crickets, chinch bugs, army worm, wheat-head army worm, and sod webworms. The measures given for control of these insect pests on corn and small grains will be found effective for combating them on grasses. In some of the western states, the range caterpillar[1] has caused considerable damage to grasses. It has been found possible to control it to some extent by introducing parasites and by cultural practices.

Occasionally large, dark-colored, thick-skinned maggots will be found around the roots of grasses in pastures. These maggots are the young of the crane flies.[2] They are often called "leather jackets." In most cases these insects are entirely harmless, feeding only on the decaying vegetable matter in the soil. One species, the range crane fly,[3] has occasionally been destructive in the West.

F. INSECTS THAT ATTACK SORGHUM, MILLET, SUDAN GRASS, AND BROOM CORN

The insects attacking these grasses and forage crops are the same as those attacking corn. The corn leaf aphid occasionally causes considerable damage to broom corn because of the discoloration of the broom-

[1] *Hemileuca oliviæ* Cockerell, Order Lepidoptera, Family Saturniidæ. See *U. S. Dept. Agr. Bur. Entomol. Bull.* 85, Part V, p. 59, 1910.

[2] Many genera and species, Order Diptera, Family Tipulidæ (see *U. S. Dept. Agr. Bur. Entomol. Bull.* 85, 1910).

[3] *Tipula simplex* Doane, Order Diptera, Family Tipulidæ (see *U. S. Dept. Agr. Dept. Circ.* 172, 1921).

corn head. Chinch bugs are very serious pests of millet and Sudan grass, making it almost impossible to grow either of these crops in areas where the bugs are very abundant. They also find Sudan grass an especially favorable place in which to pass the winter, and many of them hibernate in this grass in areas where it is grown. Millet also is one of the favorite places for second-brood army-worm moths to deposit their eggs. Control measures for these pests are given under Corn, page 318.

CHAPTER XIII

INSECTS INJURIOUS TO LEGUMES

FIELD KEY FOR THE IDENTIFICATION OF INSECTS INJURING CLOVERS, ALFALFA, SWEET CLOVER, COWPEAS, AND SOYBEANS

A. Insects that attack the plant underground:

1. Plants wilt and die during periods of dry weather. Plants are scored along the roots and often girdled near the crown, by short-snouted, dark-gray or brownish beetles or grayish-white, legless, brown-headed grubs, about $\frac{1}{6}$ inch long. Injury most severe in late spring and early fall. *Clover root curculio,* page 382.

2. Clover plants turn brown, wilt, and die. No feeding is apparent above ground but roots are found scored on the surface and tunneled through, by very small, black or dark-brown, cylindrical beetles or very small, legless, curved, brown-headed grubs about $\frac{1}{10}$ inch long. Injury is most common in old stands of clover. *Clover root borer,* page 384.

3. White, curved-bodied grubs, about $\frac{1}{8}$ inch long, with six slender legs and brown head and prothoracic shield, gnaw at the roots; chunky, light-brown beetles, $\frac{1}{10}$ inch long, feed on the leaves. *Grape colaspis,* page 385.

B. Insects that attack the leaves, buds, or stem above ground:

(*a*) *Chewing insects that eat away portions of the plant:*

1. Leaves of clover and alfalfa eaten in early spring by green, legless, curled, narrow-headed grubs with a pale stripe down the middle of the back, up to $\frac{1}{2}$ inch in length. The grubs hide about crown of plant during day and feed at night. Robust, brown, gray-mottled, oval-bodied beetles, $\frac{1}{3}$ inch long, with the thorax and head narrowed to a short snout, feed on leaves in late spring and early fall. *Clover leaf weevil,* page 385.

2. Alfalfa plants have upper leaves shredded and growing tips eaten off in spring by dark-green larvæ about $\frac{1}{3}$ inch long. Badly infested plants have a whitened, bleached appearance. Small, dark brown, grayish-mottled, oval, snout beetles about $\frac{3}{16}$ inch long feed on the leaves. Confined to Rocky Mountain region. *Alfalfa weevil,* page 387.

3. Red-clover buds dying and the growth of the plant stunted. Small, pale, brown or green, legless grubs, up to $\frac{1}{4}$ inch long, feed in the heads and inside the lateral buds. Green or bluish-green snout beetles, about $\frac{1}{8}$ inch long, with black heads and snouts, found on leaves and stems. Injury occurs in spring months only, and is most severe during dry seasons. *Clover bud weevil,* page 390.

4. Long, gray, black, or striped beetles, from $\frac{1}{2}$ to $\frac{3}{4}$ inch long feed on leaves of alfalfa during late summer and early fall. The growth of the plants is stunted and the leaves present a ragged appearance. *Blister beetles,* page 392.

5. Oval beetles about $\frac{1}{5}$ inch long, green or greenish-yellow in color and with six conspicuous black spots on each wing cover, often abundant on cowpeas and soybeans eating the leaves. *Spotted cucumber beetle,* page 311.

6. Reddish or yellowish beetles, about $\frac{1}{6}$ inch long, with three black spots near the inner edge of each wing cover, eat holes in the leaves of cowpeas. Slender, white larvæ feed on the roots and root nodules. *Bean leaf beetle,* page 453.

7. Short-snouted, dark-gray or brownish beetles, about ⅙ inch long, eat off small soybean plants on spring-broken clover sod as fast as they appear through the ground. *Clover root curculio*, page 382.

8. Alfalfa and, more rarely, clover leaves are eaten by dark-green caterpillars, about 1 inch long, with a light stripe containing a crimson hair-line along each side of the body. Caterpillars with five pairs of prolegs and three pairs of thoracic legs. Sulfur-yellow butterflies with black borders on the wings fly about over the fields. *Alfalfa caterpillar*, page 393.

9. Leaves of clover, alfalfa, soybeans and cowpeas eaten off by light-green worms, about 1¼ inch long, with a narrow white stripe and a second faint white line on each side. These caterpillars have only four pairs of prolegs in addition to the six slender thoracic legs. They drop off the plants when disturbed. Injury most common in southern part of the United States. *Green clover worm*, page 395.

10. Leaves and stems of cowpeas and alfalfa eaten by greenish, white-striped caterpillars, up to 1¾ inches long, sparsely haired, and very variable in color; the skin rough-appearing under a lens. *Corn earworm*, page 350.

11. Leaves of clover or alfalfa eaten, or plant stripped of foliage and tender shoots, by dark-green worms up to 2 inches in length with light stripes on the sides and down the middle of the back. These caterpillars, which feed at night and hide under clods, stones, or in heart of plant during the day, have a skin that appears smooth under a lens. Worms often crawl over the soil in great armies. *Army worm*, page 318.

12. Plants of clover, alfalfa, and other legumes are cut off at the surface of the ground, or leaves eaten, by plump, cylindrical worms of several shades and markings up to 1½ or 2 inches long, with six short slender legs near the head and five pairs of prolegs. *Cutworms*, page 397.

13. Soybeans and cowpeas grown near garden beans in certain sections have the leaves skeletonized by coppery-brown beetles, ¼ inch long, with eight small black spots on each wing cover; and by oval, yellow, very spiny larvæ up to ⅓ inch long which feed from underside of leaves. *Mexican bean beetle*, page 451.

14. Light webs of silk cover alfalfa plants or surface of ground about the base of the plants in newly sown fields in early fall. Yellowish-green worms, up to 1 inch long, with scattered hairs and conspicuous black spots, feed on the leaves and new growth within these webs. *Garden webworms*, page 396.

15. Irregular holes, usually extending from the margin of the leaf inward, made by brownish or grayish jumping insects up to 1½ inches long. *Grasshoppers*, page 398.

(*b*) *Piercing-sucking insects that take the sap only, causing wilting, whitening, browning, reddening and dying of the leaves and stems.*

1. Stems and leaves of clover and alfalfa covered with small, green plant lice or aphids. Plants wilt and die; leaves and stems coated with sticky fluid from the aphids. *Pea aphid*, page 398.

2. Attack similar to *B* (*b*)1 on cowpeas. *Cowpea aphid* (*Aphis medicaginis* Koch).

3. In the Rocky Mountain states, plants are stunted and seeds stuck together in pellets when threshed, by an insect similar to *B* (*b*)1. *Clover aphid*, *Anuraphis bakeri* (Cowen). (See *Idaho Agr. Exp. Sta. Bull.* 112, 1918.)

4. Leaves of clover and alfalfa have a somewhat mottled, whitened appearance due to many very fine, white spots. Numerous, elongate, active, wedge-shaped bugs, mostly less than ¼ inch long, feeding on underside of leaves. Fields swarming with these small, variously colored, flying and jumping insects. *Leafhoppers*, page 399.

(*c*) *Insects that bore in the stems:*

1. Stems of red and sweet clover are swollen or cracked open, with the pith eaten out. Stems sometimes break off. Yellowish, smooth-sided, cylindrical worms about ½ inch long with two curved hooks at end of body, feeding on the pith in these

tunnels. Parent beetle a smooth, narrow, hard-shelled insect 1/3 inch long with blue wing covers and bright red head and prothorax. *Clover stem borer*, page 400.

C. Insects that attack the heads, flowers, or seeds:

1. Seeds of red and other clovers and alfalfa each completely occupied and later broken and cracked open, by a very small, fat, white, legless, maggot-like larva that reaches full growth inside the seeds. Infested seeds are often dull-colored. Eggs laid by very small, black, four-winged, wasp-like insects, 1/16 inch long, that fly about fields and crawl over the heads. *Clover seed chalcid*, page 401.

2. Red-clover heads fail to develop evenly, only a part of the pink florets opening, the rest of the head remaining green. Very small, pinkish, legless maggots, 1/12 inch long, feeding on the outside of the green seeds causing them to shrivel and dry up. *Clover seed midge*, page 405.

3. Red-clover heads with much the same appearance as in *C*, 2, but with a small, somewhat hairy caterpillar, about 1/4 inch long and with distinct head and legs, feeding on the developing seeds and destroying many of the florets at the base. *Clover-head caterpillar*, page 403.

4. Cowpeas in the pod, or in storage, contain white, footless grubs or short, chunky, brownish beetles, about 1/10 inch long. Both beetles and grubs feed inside seed, later leaving the seed through a small round hole. *Cowpea weevil or four-spotted bean weevil*, page 408.

A. CLOVER AND ALFALFA INSECTS

Clover Root Curculio[1]

There are several species of clover root curculios, or clover Sitones, that attack red, sweet, and alsike clover and alfalfa. Our knowledge of the different species is incomplete. Probably the most important is *Sitona hispidulus* Fabricius, but there are two other common species.[2]

Importance and Type of Injury.—Clover or alfalfa plants infested by these insects wilt and often die, especially during periods of dry weather. If the plant is dug and examined, the roots will be found scored and furrowed on the outside with numerous burrows, oftentimes nearly girdled (Fig. 250). The leaves in infested fields will show numerous rather regular areas eaten out, or the leaves entirely eaten off. Small, grayish-white, footless, brown-headed grubs, about 1/6 inch long, will be found on the roots. Small, grayish or brownish beetles, of about the same length, with blunt, short snouts (Fig. 251), may be found feeding upon the leaves of the plants during the day, or hidden away among the trash on the ground or around the crown of the plant.

Plants Attacked.—The insects feed on all the common clovers, alfalfa, soybeans, and cowpeas, and doubtless on some other legumes. White clover seems to be slightly preferred by the insects, although they are often very abundant on the other varieties of clover as well as on alfalfa.

Distribution.—These insects are quite generally distributed over the United States and southern Canada. These species are probably all of

[1] *Sitona* spp., Order Coleoptera, Family Curculionidæ.

[2] *Sitona flavescens* Marsham, and *Sitona crinitus* Gyllenhal.

European origin, but have been known in North America for at least 60 years.

Life History, Appearance, and Habits.—The winter is passed in the egg, adult, and larval stages. Most of the insects pass the winter as young larvæ. In the spring these larvæ develop by feeding on the clover roots and crown of the plant, pupate during late March and April and emerge during May and June as beetles. These beetles feed actively for about 1 month or 6 weeks, often when abundant doing considerable damage to clover fields. They become less active during the middle of the summer, and although they remain about the clover fields, they feed

Fig. 250.—Work of clover root curculio on alfalfa root, about three times natural size. (*From Ill. State Nat. Hist. Sur.*)

Fig. 251.—Adult clover root curculio, *Sitona flavescens* Marsham, enlarged about twelve times. (*From Ill. State Nat. Hist. Sur.*)

but little. In the early fall they again become active, feed and mate, and the females deposit their eggs about the crowns of the plants. The eggs are laid at intervals extending over several weeks, egg laying often taking place as late as the middle of November. Nearly all the eggs hatch in the fall but some hatch the following spring. A considerable number of beetles survive the winter and some eggs are laid in the spring, at least in the mid-western states.

Control Measures.—Practically no effective control measures for combating these insects have been developed. Rotation which will put infested fields in a grass or cultivated crop will drive out the beetles. If the land is plowed late in the fall or early in the spring, practically all of the insects in the field will be destroyed. If on the other hand the land is plowed early in the fall many of the adult beetles will migrate out

of the field and crawl considerable distances to other fields containing crops on which they feed and survive.

References.—*Ill. Agr. Exp. Sta. Bull.* 134, 1909; *U. S. Dept. Agr. Farmers' Bull.* 649, 1915.

Clover Root Borer[1]

Importance and Type of Injury.—Infested clover plants turn brown, wilt, and die, generally having the appearance of suffering from the attack of some disease. An examination of the roots, however, will show numerous burrows running through them and also grooves on the surface of the roots (Fig. 252). These burrows cut off the circulation of the plant, and frequently kill it. Small, white, brown-headed, footless grubs, about $\frac{1}{10}$ inch long, will be found boring in the roots. Dull black or dark brown, somewhat hairy, cylindrical, hard-bodied beetles, about $\frac{1}{12}$ to $\frac{1}{10}$ inch in length, may be found in the burrows in the roots or around the crown of the plant.

Fig. 252.—Tunnels of the clover root borer, *Hylastinus obscurus* (Marsham), in clover root. About natural size. (*From Webster, U. S. D. A.*)

Plants Attacked.—This insect prefers red, alsike, and mammoth clover. It has also been taken on white and sweet clover and alfalfa, but is apparently of little importance on the last three. It has been known to infest peas.

Distribution.—The clover root borer is distributed over the United States, with the possible exception of the southwestern states, and occurs also in eastern Canada. It is of European origin and was probably brought into this country some time about 1870.

Life History, Appearance, and Habits.—The insect passes the winter in the larval and adult stages, nearly all the insects being in the adult stage. The winter is passed in the ground in the clover roots. In the spring, the female beetles deposit their eggs in cavities eaten out in the crown of the clover plant, or on the sides of the roots, or in burrows inside the clover roots. Egg laying extends over the spring months. The larvæ, upon hatching, tunnel through the roots, making irregular, branched burrows. They become full-grown during late summer and transform to pupæ during midfall. All stages of the insect can be found during the late summer and fall months. There is but one generation each year.

[1] *Hylastinus obscurus* (Marsham), Order Coleoptera, Family Scolytidæ.

Control Measures.—The clover root borer is seldom seriously destructive except in fields where clover has been allowed to stand more than two seasons. If a field is found seriously infested by these insects, there is no method of cleaning them out other than plowing up the clover and putting the ground in some non-legume crop. Where clover is allowed to stand for only two seasons, very little trouble from this insect is experienced.

Reference.—U. S. Dept. Agr. Bur. Entomol. Circ. 67, 1905.

Grape Colaspis

This insect has been fully covered as a pest of corn, which is the crop most seriously damaged by it (see page 313). It sometimes causes

Fig. 253.—Injury to clover foliage by beetles of the grape colaspis, and an adult, natural size. (*From Ill. State Nat. Hist. Sur.*)

considerable injury to clover plants by the feeding of the grubs on the clover roots. The adults eat the leaves (Fig. 253). No method of control on the clover plant has been developed.

Clover Leaf Weevil[1]

Importance and Type of Injury.—The damage by this insect is most apparent in clover fields during the early spring. At this time of the year, the leaves of the clover or alfalfa plants will be found with smooth-edged notches eaten out of their sides, or occasionally with whole leaves eaten off. Small, green, fat-bodied, legless larvæ will be found hidden

[1] *Hypera punctata* (Fabricius), Order Coleoptera, Family Curculionidæ.

away around the base of the clover plants, occasionally feeding on the leaves. Their bodies are nearly always curved so that the head and tail nearly touch. There is a pale, yellowish-white stripe, edged with red, down the center of the back. The full-grown larvæ are approximately $\frac{1}{2}$ inch in length (Fig. 254).

Plants Attacked.—Clover, including sweet clover, and alfalfa are the main plants fed upon by the larvæ of this beetle. Beans have been very little injured. The adult insects feed on a great variety of flowers, and have been observed in large numbers on goldenrod, and also on the heads of wheat, as well as many of the common weeds and flowering plants.

Distribution.—This insect is probably a native of southern Europe. It was not known in this country until 1880, when it was first reported

Fig. 254.—Larva of the clover leaf weevil, *Hypera punctata* (Fabricius), about three times natural size. (*From Ill. State Nat. Hist. Sur.*)

as injuring clover in New York. It has now spread over most of the United States and into Canada.

Life History, Appearance, and Habits.—This insect passes the winter mainly in the form of partly grown larvæ; to a lesser extent in the egg stage; and to a still lesser extent in the full-grown or adult beetle stage. The overwintering beetles are of little importance, as they die early in the spring and probably never lay eggs except in the fall of the year. All eggs have hatched by early spring and the young larvæ feed mainly at night on the leaves. During the day, they remain well hidden in trash on the surface of the ground, or about the crown of the plants. The larvæ become full-grown during late spring and spin coarse brown or greenish-brown cocoons just beneath the ground surface or about the crowns of the plants, or occasionally on the stems of the leaves. These cocoons are thin, about $\frac{1}{3}$ inch in length, and have the appearance of a coarse network of somewhat stiff threads. The pupal stage is passed in this cocoon, the adult beetle coming out in early summer. The beetles are dark brown, flecked with black on the back and paler brown underneath. A strong, robust snout projects from the head (Fig. 255). The beetles feed quite actively for a short time after emerging from the

cocoon, and then become rather sluggish and feed but little until fall; they again become active in the fall, mating takes place, and the females lay their eggs mainly during October. The eggs are pale yellow in color, and are deposited in the stems of the leaves, on the stalks, or about the crown of the food plant. Most of these eggs hatch during the late fall, but a few of them do not hatch until the following spring.

Control Measures.—It is difficult to apply any direct control measure to fields infested by these insects that will kill the beetles without injuring the plants. In most seasons, the insects are held in check by a fungus

FIG. 255.—Adult of the clover leaf weevil, *Hypera punctata* (Fabricius), about six times natural size. (*From Ill. State Nat. Hist. Sur.*)

disease which attacks the larvæ. The larvæ infested with this disease turn yellowish and later brownish in color, and usually remain curled around the tips of the leaves during the daytime, not hiding away as do the healthy larvæ. Where numbers of the insect are found in this condition, one may be sure that little damage to the crop will result, although the weevils may be very abundant in the field. Clover fields that are found very heavily infested early in the spring, so that growth has practically stopped and the plants are being killed, should be plowed up and planted to some of the grass crops, or, where possible, to small grain. The insects are very difficult to poison.

References.—*Ill. Agr. Exp. Sta. Bull.* 134, 1909; *U. S. Dept. Agr. Dept. Bull.* 922, 1920; *N. Y.* (*Cornell*) *Agr. Exp. Sta. Bull.* 411, 1922.

ALFALFA WEEVIL[1]

Importance and Type of Injury.—During recent years, this insect has become the most important alfalfa pest in the United States. The

[1] *Phytonomus posticus* (Gyllenhal), Order Coleoptera, Family Curculionidæ.

plants attacked show a skeletonizing or shredding of the tips of the new growth, this injury increasing from early spring until shortly before the time of the first cutting of alfalfa. In heavily infested fields, the growing tips are eaten off, the growth of the plants stunted, and the green part of the leaves eaten out to such an extent that the fields appear to be suffering from severe frost injury, presenting a bleached-out appearance. The plants are covered with green larvæ a little less than $\frac{1}{2}$ inch long

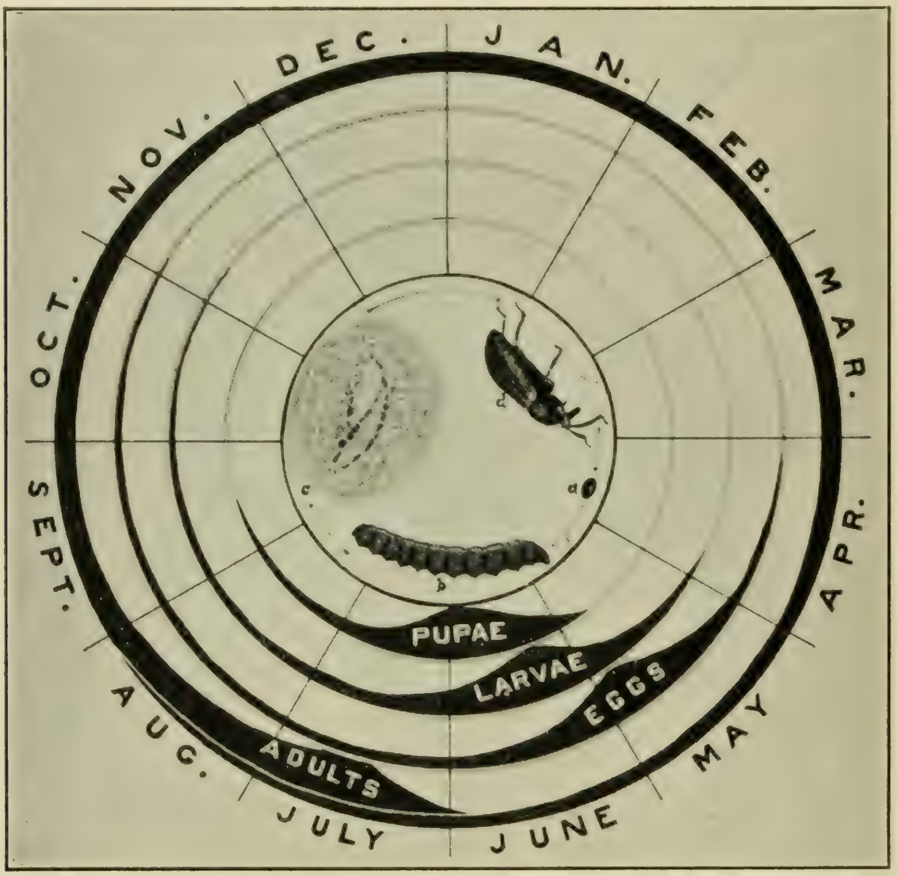


Fig. 256.—Diagram of seasonal history of the alfalfa weevil in Colorado. *a*, egg; *b*, larva; *c*, pupa in cocoon; *d*, adult. Enlarged three times. (*From Eleventh Ann. Rept. State Ent. Colorado*, 1919.)

when full-grown. They are plump-bodied, legless, but with well-developed ridges on the underside of the body which take the place of legs (Fig. 256, *b*). The adult snout beetles (*d*) will also be found in numbers during the spring and early-summer months in the injured fields.

Plants Attacked.—Alfalfa is practically the only food plant of this species.

Distribution.—The insect was probably imported from southern Europe some time about 1900. The first noticeable injury occurred in the vicinity of Salt Lake City, Utah, in 1904. Since then, the insect has spread to include within its range the large alfalfa-growing districts

of the West, reaching to Colorado, Idaho, Montana, Wyoming, Nevada, California, and Oregon. It has spread at the rate of twenty miles or more per year, the rate of spread depending on the type of farming, and the natural factors in the different areas where it is working.

Life History, Appearance, and Habits.—This weevil (Fig. 256, *d*) winters only in the adult stage. The beetles are dark brown, or nearly black, with short grayish hairs giving them a somewhat spotted appearance. They are about 1/8 inch long with a medium sized beak about one-half the length of the thorax, projecting downward from the front of the head. On leaving their hibernating quarters about the crowns of the alfalfa plants, or under leaves and rubbish, the beetles feed for a few days, and mate, and the females lay their eggs (*a*) in the stems of the alfalfa. They first make cavities in the stems with their beaks, and in these insert from one to as many as 40 eggs. Each female beetle lays from 600 to 800 eggs during the spring. The larvæ on hatching are nearly white but soon become green (*b*). They make their way to the opening leaf buds at the tip of the plants, and there commence feeding. This stunts the plant and produces a new growth below the tip which in turn is eaten off by the weevil larvæ. In heavily infested fields, practically the entire first cutting is ruined and the growth of the second crop is delayed. Most of the larvæ become full-grown about the time of cutting the first crop. They then go to the ground, and spin a net-like, nearly spherical cocoon (*c*) in which they change to the pupal stage. After about 10 days in this stage, they emerge as adults. These adults feed on the alfalfa plants the remainder of the summer and go into winter quarters early in the fall.

Control Measures.—A fair degree of control of the alfalfa weevil has been obtained in some sections from the importation of a parasite.[1] In certain areas in the West, this parasite has become sufficiently abundant to constitute an effective check to the increase of the weevil during certain years. In other areas, it has not proved effective. Apparently it can never be depended upon fully to prevent damage by the weevil.

The most effective control measures against this insect in most of the areas where it is now present are either spraying or dusting with a stomach poison. Arsenate of lead used as a spray, or calcium arsenate as a dust, have given the best results. In spraying with arsenate of lead, Reeves has found that the best time to make the application is when the young larvæ become sufficiently abundant almost to stop the growing of the alfalfa plants. As the eggs hatch over a considerable period, it is necessary to wait until this time to get all the insects with one spray. The best time to apply the spray is usually about 2 weeks before the first-crop alfalfa is normally ready for cutting. Spraying at this time with arsenate of lead at the rate of 2 pounds of the powdered

[1] *Bathyplectes curculionis* (Thomson), Order Hymenoptera, Family Ichneumonidæ.

material to 50 gallons of water and applying the spray at the rate of 100 gallons per acre, has given almost a complete control of the weevil. Spraying the alfalfa stubble after the first crop has been cut has not, in general, proved effective. As in all spraying operations, thorough work must be done at the right time in order to get a satisfactory control. During the last few years, almost as good control has been obtained by dusting, using calcium arsenate mixed with sulfur as a carrier. Other methods of control, which have not been found as effective, but which are of some value, consist of dragging the field after the first cutting is removed, with a brush drag which knocks the larvæ from the stubble, and causes their death by contact with the hot dry ground. Dragging the field with a brush or wire drag after it has been harrowed, to create a dust mulch around the crowns of the plant has given fairly good results, but spraying and dusting are by far the best methods of control.

References.—U. S. Dept. Agr. Farmers' Bulls. 741, 1916; and 1185, 1920; and 1528, 1927; *Colo. Agr. Exp. Sta. Circ.* 33, 1923.

Clover Bud Weevil[1]

Importance and Type of Injury.—The clover bud weevil since about 1910 has become one of the most important and destructive pests of red clover in the middle-western states. Infested clover plants show a deadening of the leaves and a general checking of the growth, which is particularly noticeable during dry seasons. If such plants are examined, small slits will be found cut in the stem, usually just above an axil of the stem or at the lateral buds, and the buds eaten into both at the terminal and on the sides of the stems. The heads of the plant become stunted and misshapen. Examinations made during May will show small pale-green larvæ which are feeding in the stems, the newly forming buds, or the florets in the head. The injury is most severe during dry seasons, and frequently amounts to an infestation of 90 to 98 per cent of all plants in the field.

Plants Attacked.—The insect seems to prefer red clover, but feeds on all of the common species of clovers, and also on sweet clover and alfalfa. On the last two named plants, it has been of little importance.

Distribution.—The insect was probably introduced into this country in the eastern part of Canada some time about 1875 or 1880. It has now spread over the entire eastern half of the United States and into the Pacific Northwest. In the mid-western states it has increased very rapidly in abundance since about 1915.

Life History, Appearance, and Habits.—The winter is passed only in the adult stage, the overwintering beetles being about ⅛ inch long, of a beautiful deep green, or blue-green color, with small black heads

[1] *Phytonomus nigrirostris* Fabricius, Order Coleoptera, Family Curculionidæ (also called lesser clover-leaf weevil).

and a glossy-black, slender beak approximately as long as the thorax (Fig. 257). They shelter to some extent around the crowns of the clover plants in the field, but, in Illinois, have been found in greatest abundance in woodland areas. A number of hibernating adults have been taken from around the base of a single tree or stump in the center of large areas of heavy woodlands. They are also found along bushy hedges, fences, roadsides, and other areas where trash occurs to give protection from the winter weather. They fly from their hibernating quarters about the time clover growth starts in the spring. The adults feed for a few days on the clover leaves, and the females begin laying their eggs. The eggs are deposited in small slits, cut in the stem of the clover

FIG. 257.—Adult clover bud weevil, dorsal and side views. About five times natural size. (*From Ill. State Nat. Hist. Sur.*)

plant or in the bud at the axil of the leaf or in the terminal bud of the plant. Usually but one egg is laid in a place, although two or three have occasionally been found. Egg laying extends over nearly a month, each female laying a total of from 200 to 300 eggs. The eggs hatch in from 2 to 3 weeks, and the young larvæ, which are at first white, but later change to a brownish-white, begin feeding on the plant tissue. Where feeding starts at the buds, these may be entirely killed. If they start feeding in the head, it is destroyed entirely or in part. They occasionally tunnel in the stems, causing the stem above the point where they are working to wilt and die. The larval period extends from 20 to 25 days, or possibly somewhat longer, depending on the weather conditions of the season. Full-grown larvæ spin their cocoons on the ground around the base of the plant, but more commonly in the part of the plant where they have been feeding. These cocoons are elliptical, or nearly round, about $\frac{1}{7}$ inch across. They are transparent, of a somewhat whitish, or yellowish-white color. The insects remain in the pupal stage for from 5 to 12 days, emerging as full-grown beetles about 10 days before the time for cutting the first crop of red clover. Newly emerged beetles are brown in color, but begin to show green by

the end of 1 or 2 days, and by the third or fourth day after emergence are a pronounced grass green. They feed in the clover field for 2 to 3 weeks, gradually becoming less abundant as they fly from the field to seek shelter in which to pass the winter. In Illinois, most of the beetles have left the fields by mid-July. There is probably only one generation of the insect each season.

Control Measures.—No satisfactory method of control for this insect has yet been developed. Spraying, dusting, and cultural practices that have thus far been tried have proved of no value. Clover on fertile soil during a moderately wet or wet season will not suffer severely from the attacks of this insect; but on poor soil in a normal year, or in a dry season, will be severely damaged.

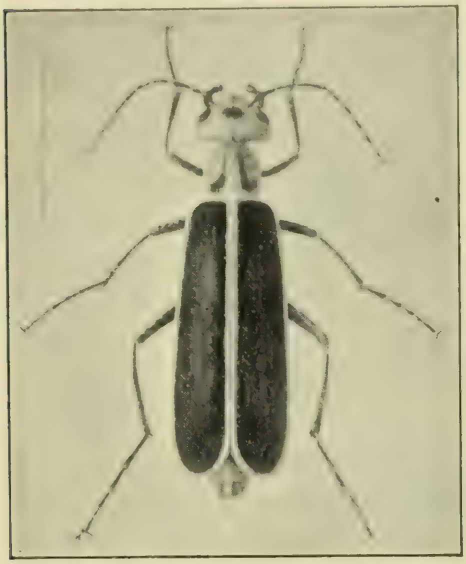


Fig. 258.—Adult of the margined blister beetle, *Epicauta marginata* Fabricius. Line shows natural length. (*From Ill. State Nat. Hist. Sur.*)

Reference.—Ohio State Univ. Ext. Bull; Vol. 16, No. 10, 1920–1921.

Blister Beetles[1]

Importance and Type of Injury.—Clover and alfalfa are rarely, if ever, seriously damaged by these insects. Frequently, however, they are present in such numbers in alfalfa fields as to cause some alarm and a little damage. The long, black, gray, or striped black-and-yellow beetles, with very conspicuous heads and necks (Fig. 258), will be found clustered on the tips of alfalfa and clover plants, feeding on the flowers and leaves. Growth of the plants is somewhat stunted, and the field presents a ragged appearance where the beetles are numerous.

Plants Attacked.—Blister beetles are general feeders attacking many flowering plants, field and garden crops, and weeds.

Distribution.—Throughout the United States and arable parts of Canada.

Life History, Appearance, and Habits.—The blister beetles whose life histories are known pass the winter in the larval stage. The larvæ of some species feed on the eggs of grasshoppers and others in the cells of certain burrowing bees. They have a very interesting and complicated life history. Those which feed on the eggs of grasshoppers are, of course, beneficial in their larval stage. Some of the blister beetles which feed on clover and alfalfa, notably the gray blister beetle, has two generations a year. Nearly all of the other species have only one. The

[1] *Epicauta* spp., *Cantharis* spp., *Macrobasis* spp., Order Coleoptera, Family Meloidæ.

adult beetles vary in appearance, the gray blister beetle, and the black blister beetle being of a uniform color and from ½ inch to nearly 1 inch in length. Several other species are spotted, striped, or marked with different colors (see also p. 474).

Control Measures.—Probably the best control for blister beetles on alfalfa or clover is to go over the field with a hopperdozer as described for catching grasshoppers. Once over the field with this machine will probably clean out the blister beetles. In most cases it is not necessary to take any active steps to combat these insects on clover and alfalfa.

Reference.—*U. S. Dept. Agr. Dept. Bull.* 967, 1921.

Alfalfa Caterpillar[1]

Importance and Type of Injury.—This insect is particularly a pest of alfalfa in the southwestern states. Infested fields show part of the leaves eaten out, or the leaves entirely consumed by a green worm, which in the southern states appears during late February or March. Previous to the appearance of the worms, sulfur-yellow butterflies with black margins on the upper surface of the wings will be found in large numbers hovering over the alfalfa plants, on which they are depositing their eggs.

Plants Attacked.—The insects feed mainly on alfalfa, although they are occasionally taken on clover and several other legumes.

Distribution.—The alfalfa caterpillar is found throughout the United States and southern Canada, with the possible exception of the extreme southeastern United States. Its heaviest damage, however, occurs in the Southwest, and the alfalfa-growing regions along the Pacific slope.

Life History, Appearance, and Habits.—Throughout most of its range the insect passes the winter in the pupal stage (Fig. 259, *C*) on the plants. In the extreme southern part of its range, larvæ may be found during the winter months, and, occasionally, adults will be seen on the wing in these sections; so it probably hibernates in all stages. In the spring, the overwintering pupæ change to yellow butterflies (Fig. 259, *B*) having a wing expanse of about 2 inches. The entire under surface of the wings is solid sulfur yellow. The upper surface of the wings is bordered with black. The butterflies, on emerging, lay their eggs to the number of from 200 to 500, on the undersides of the alfalfa leaves. These eggs hatch in a few days into small dark-brown worms which soon change to a green color. The worms grow very rapidly, becoming full-grown in from 12 to 15 days, at which time they are nearly 1½ inches in length, of a dark grass-green color, with a fine white stripe on each side of the body, through which runs a very fine red line (Fig. 259, *A*). These worms change to the pupal stage without spinning a cocoon. They attach the narrow tail end of the pupa to the alfalfa stalk and throw a

[1] *Eurymus eurytheme* Boisduval, Order Lepidoptera, Family Pieridæ.

loop of silk about their bodies a little above the middle, which holds the head upright. The pupal stage lasts from 5 to 7 days before the emergence of the adult butterflies. In the extreme southwestern states, there are from five to seven generations a year, while probably at least two generations always occur in the northern part of the insect's range.

Control Measures.—Spraying or dusting the crop as recommended for the alfalfa weevil, will serve as an effective control for the alfalfa caterpillar. Such measures should be taken only when the insect is very

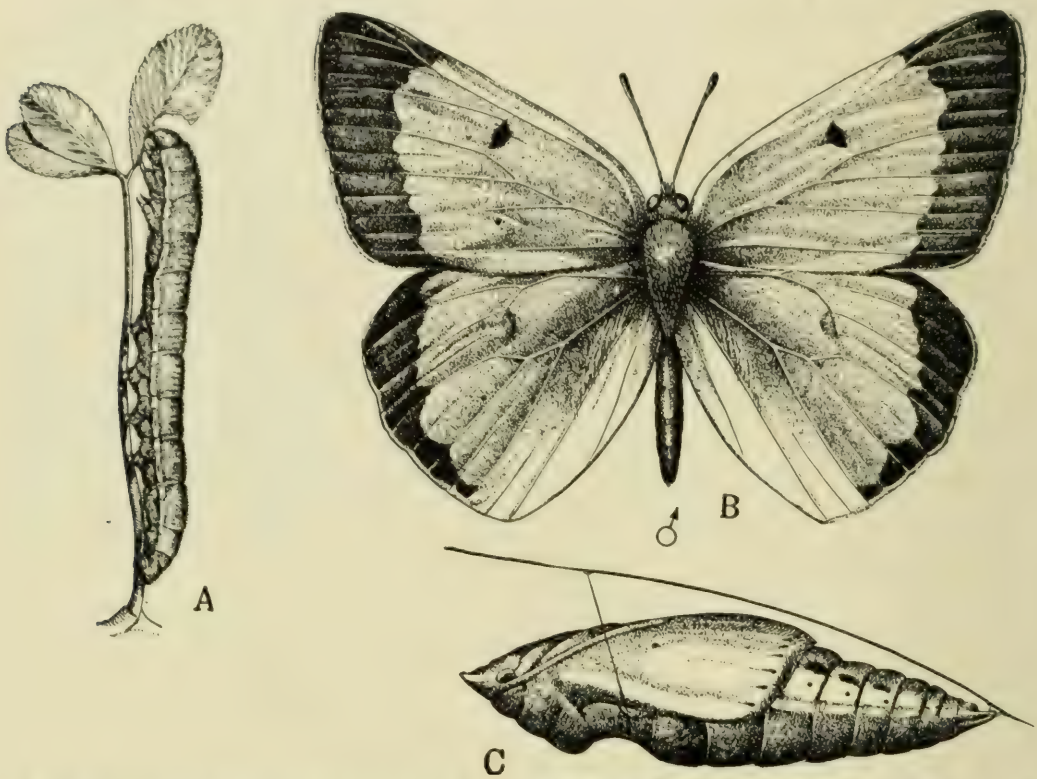


FIG. 259.—The alfalfa caterpillar; *A*, full-grown larva feeding on leaf; *B*, adult male butterfly; *C*, chrysalid or pupa, showing how it is suspended from the plant. Slightly enlarged. (*From U. S. D. A. Dept. Bull.* 124.)

abundant and serious damage to the crop is threatened. Cutting the infested alfalfa as low as possible and removing the hay from the field is also an effective control measure. This cuts off the food supply of the young caterpillars and exposes them to their insect enemies, of which several kinds are nearly always present in the infested fields. Many caterpillars are also killed by exposure to the heat of the sun. In cutting, care should be taken that the field is left clean, without a sufficient amount of leaf growth to support the growing caterpillars until they mature. Keeping down weed growth around the field is also of considerable help in control. Pasturing, where it can be properly done, so that the animals are not left too long on the field, also is recommended. It is of the greatest importance that alfalfa growers know the parents of this caterpillar

and when swarms of the yellow butterflies (Fig. 259, *B*) are noted about the field, keep close watch of the growing alfalfa crop and if necessary take the control measures above recommended before the worms have caused serious damage.

References.—U. S. Dept. Agr. Farmers' Bull. 1094, 1920; *U. S. Dept. Agr. Dept. Bull.* 124, 1914.

Green Clover Worm[1]

Importance and Type of Injury.—The green clover worm is only occasionally of importance as a pest of clover and alfalfa. It is nearly always present in fields of these

Fig. 260.—Larva of the green clover worm, *Plathypena scabra* Fabricius, and its injury on clover. About natural size. (*From Ill. State Nat. Hist. Sur.*)

crops grown in the eastern United States. When it is abundant, the infested fields present a ragged appearance, many of the leaves having been eaten off by green worms with two narrow white stripes down each side of the body (Fig. 260). The insect is more important in the southern than in the northern states.

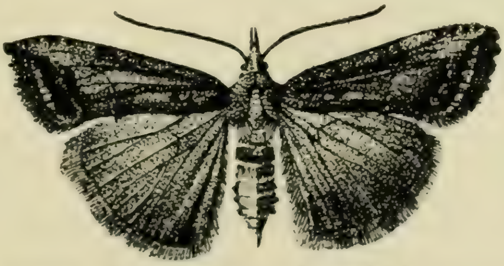


Fig. 261.—Adult of the green clover worm, enlarged about one-half. (*From Ill. State Nat. Hist. Sur.*)

Plants Attacked.—Alfalfa, clover, soybeans, cowpeas, vetch, strawberry, raspberry, and many of the common weeds and other legumes.

Distribution.—Eastern United States to the plains states and southeastern Canada.

Life History, Appearance, and Habits.—The green clover worm passes the winter in the pupal or adult stage. The adults are dark brown, black-spotted or mottled moths with a wing expanse of about 1¼ inches (Fig. 261). When at rest, the wings are held in such a position as to give the insect a triangular appearance. The moths

[1] *Plathypena scabra* Fabricius, Order Lepidoptera, Family Noctuidæ.

shelter around barns, hay stacks, and other protected places. They become active about the time clover growth is well started, and, after mating, the females lay their eggs singly on the undersides of the leaves of the plants which they attack. The eggs hatch into small worms which are nearly the shade of the alfalfa leaf. They feed on the leaves, completing their growth under normal conditions in about 4 weeks. They then crawl down the plant and work their way under litter or just below the surface of the soil, where they change, inside a light silken cocoon, to a brown pupal stage. They remain in this stage for from 10 days to 3 weeks and then emerge as moths. There are from three to four generations in the southern part of the United States, and probably two in the northern part of the insect's range.

Control Measures.—In most years these insects are not sufficiently abundant to necessitate taking active measures of control. When fields are being injured, the alfalfa or clover should be cut as soon as possible and removed from the field. This exposes the worms to the bright sunlight and to their insect and bird enemies, and is usually the only control measure necessary. Hopperdozers have been used with a fair degree of success in combating the insects.

References.—*U. S. Dept. Agr. Farmers' Bull.* 982, 1918; *U. S. Dept. Agr. Dept. Bull.* 1336, 1925.

GARDEN WEBWORM[1]

Importance and Type of Injury.—This insect is of some importance on clover, but is more particularly a pest of alfalfa and some other crops. During the spring and summer months, fields that are infested with this insect will show light webs over the leaves, in which will be found greenish to yellowish-green, somewhat hairy worms with black dots over their bodies (Fig. 262). When full-grown, they are an inch or a little over in

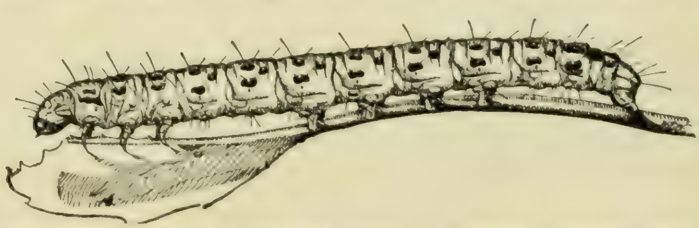


FIG. 262.—The garden webworm, *Loxostege similalis* Guenee, caterpillar or "worm," about twice natural size. (*From U. S. D. A. Farmers' Bull.* 944.)

length with a light stripe extending down the middle of the back and with three dark spots on the side of each segment, from each of which projects one to three bristle-like hairs. When disturbed, the worms drop to the ground. Fields that are heavily infested will show a considerable amount of webbing over the alfalfa, and the leaves inside these webs will be nearly all eaten off. In the fall, the worms work in somewhat the same manner as cutworms on the newly sown alfalfa. At this time, they hide in silken-lined burrows on or in the ground to which they retreat when disturbed.

Plants Attacked.—The garden webworm is a general feeder. Among the plants attacked are alfalfa, clover, beans, soybeans, cowpeas, sugar beets, peas, strawberries, wild sunflower, thistles, pigweed, ragweed, sweet clover, lamb's-quarters, and a number of others.

[1] *Loxostege similalis* Guenee, Order Lepidoptera, Family Pyralididæ.

Distribution.—The insect is native to both North and South America, and occurs generally in the farming areas of the United States, Canada, and Mexico.

Life History, Appearance, and Habits.—The winter is passed in the pupal stage in the soil about the plants on which the fall generation of larvæ fed. In the extreme South it is possible that some of the insects live through the winter in the larval stage. Adult moths emerge from the pupæ early in the spring and deposit their eggs on the leaves of their food plants. The eggs are laid in masses of from 4 or 5 to 50. The moths are about 3/4 inch across the wings, buff colored with shadings and irregular markings of light and dark gray. They are rather weak insects, probably living but a short time. When one is going through infested fields, they will frequently fly up, going a short distance, but usually alighting within a rod or two of the point where they were first disturbed. The larvæ hatch from the eggs in 3 days to 1 week. They begin feeding on the leaves, protecting themselves inside the light webs above described. It usually requires about 3 weeks for the worms to reach the full-grown stage and go into the ground for pupation. The pupal period is ordinarily 7 to 10 days. There are several generations each season. Sanborn states that there are five full generations each year in Oklahoma. In the northern part of the range, there are probably two or three generations each season.

Control Measures.—Fields which become infested during the summer months, can usually be cleaned of the webworms by cutting the alfalfa. This cuts off the food supply of the worms, as they are unable to feed on the dried alfalfa hay, and also by destroying their webs exposes many of them to bird and insect enemies. Fields of newly seeded alfalfa infested in the early fall may be protected by dusting with calcium arsenate at the rate of about 10 pounds per acre, or spraying with calcium arsenate or arsenate of lead, 2 pounds to 50 gallons of water, applied at the rate of about 100 gallons per acre. Either one of these methods is very effective in killing the fall generation of larvæ provided a thorough application of the poison is made. Keeping field margins closely cut to keep down all growth of the weeds on which this insect feeds is also of considerable help in preventing damage. Insect parasites usually prevent damage for more than 1 year successively.

References.—*Okla. Agr. Exp. Sta. Bull.* 109, 1916; *U. S. Dept. Agr. Farmers' Bull.* 944, 1918.

Cutworms

Several species of cutworms are troublesome in clover and alfalfa fields. In the mid-western states the variegated cutworm[1] (Fig. 263) is the one most generally abundant in clover and alfalfa during the spring and summer months. The dingy

[1] *Lycophotia margaritosa saucia* Hübner, Order Lepidoptera, Family Noctuidæ.

cutworm,[1] clay-backed cutworm,[2] and several others are also common in fields of clover and alfalfa at this time of the year. In the fall, newly sown alfalfa fields are often seriously damaged by the yellow-striped army worm,[3] and the fall army worm.[4] Both these insects migrate up from the South and the moths lay their eggs in the newly sown alfalfa. The worms hatching from these eggs feed on the alfalfa in the general manner of cutworms, not infrequently destroying the entire field. Several

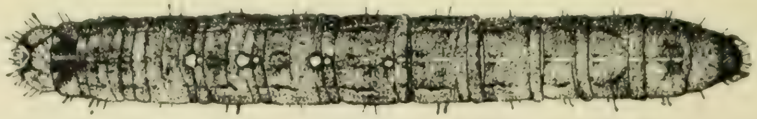


FIG. 263.—Larva of the variegated cutworm, dorsal view. Enlarged about one-half. (*From Ill. State Nat. Hist. Sur.*)

other species of cutworms are abundant in clover and alfalfa in different parts of the country.

Control Measures.—Cutworms may be controlled in these crops by the use of the poison-bran bait, made and applied in the manner described for the control of these insects on corn (see page 323).

References.—*U. S. Dept. Agr. Farmers' Bull.* 739, 1916; *Dom. Canada, Dept. Agr. Bull.* 22, 1923.

Army Worms

The true army worm and the western army cutworm[5] often feed on clover and alfalfa to a limited extent. They prefer the grass crops, however, and normally cause but little damage to legumes. Occasionally army-worm outbreaks are associated with outbreaks of the variegated cutworm, and these latter insects, which prefer legumes, may cause serious damage to clover fields, which is mistaken for damage by the army worm

Control Measures.—The control is the same as that given on page 319.

Grasshoppers

Grasshoppers are often the cause of serious damage to clover and alfalfa. For control measures, see pages 330 .

Pea Aphid

This insect has been treated under Pea Insects (see p. 455). On clover and alfalfa, where it is often a very serious pest, an effective method of control is to cut the clover and alfalfa as early as possible, when these crops have become heavily infested with the pea aphid. A brush drag may be used on the alfalfa stubble. Smith, in Kansas, recommended burning over heavily infested areas in the fall of the year.

[1] *Feltia subgothica* Haworth.

[2] *Feltia gladiaria* Morrison.

[3] *Prodenia ornithogalli* Guenee.

[4] *Laphygma frugiperda* Smith and Abbott.

[5] *Chorizagrotis auxiliaris* Grote, Order Lepidoptera, Family Noctuidæ.

LEAFHOPPERS[1]

Importance and Type of Injury.—Where leafhoppers are abundant in any crop, the plants show a lack of vigor, growth is retarded, and in most cases the leaves have a somewhat whitened, mottled appearance, due to sucking out of the sap by the hoppers, which feed mainly on the undersides of the leaves. In walking through infested fields, large numbers of tiny mottled or speckled, green, yellow, brown-gray, or various colored insects (Fig. 264) will hop or fly for short distances ahead of one. With certain species of leafhoppers, the feeding produces a burning effect on the plants, and causes the tips to wither and die somewhat as though scorched by bright sunshine or injured by drought. Some species are carriers of

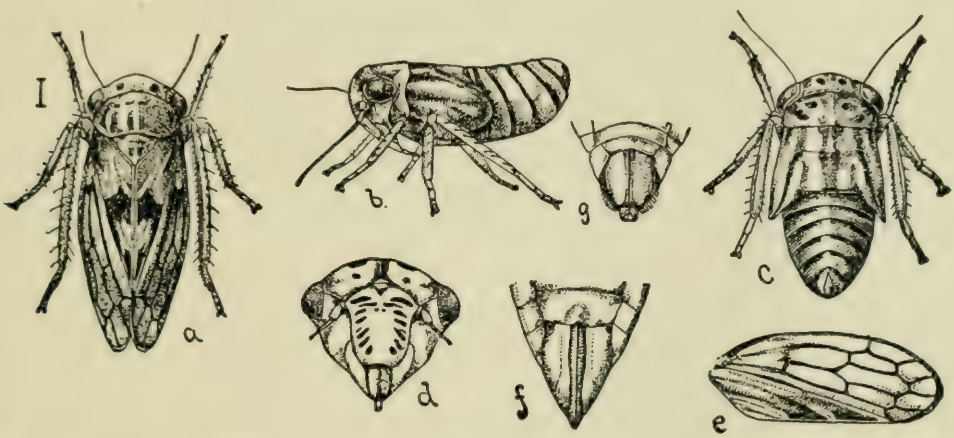


FIG. 264.—The clover leafhopper, *Agallia sanguinolenta* Provancher *a*, adult; *b*, nymph, side view; *c*, nymph, dorsal view; *d*, face; *e*, front wing; *f*, female and *g*, male genitalia and last segment. The line shows natural size. (*From Osborn and Ball.*)

plant diseases. See apple leafhopper (p. 475) and beet leafhopper (p. 512).

Plants Attacked.—Nearly all cultivated and wild plants are attacked by various species of leafhoppers. All of the clovers, alfalfa, and many of the grasses and small grains, also orchards, vineyards, and forest and shade trees are infested and damaged to some extent.

Distribution.—Leafhoppers occur throughout the world.

Life History, Appearance, and Habits.—The winter is passed in various stages, according to the different species. Some go through the winter in the egg stage in the stems of various plants, a large number of species pass the winter in the form of full-grown insects, which hide away in shelters around and in the field crops which they attack, while a few pass the winter in the partly developed, or nymphal stages. In most cases that are known, the insects lay their eggs in the stems, buds, or leaves of their food plants. These hatch into wingless but very active nymphs. The nymphs feed by sucking the sap and sometimes inject a substance which is distinctly poisonous to the plant tissue, and kills the areas

[1] Many species of the Order Homoptera, Family Cicadellidæ.

around their feeding punctures. They develop from small nymphs to adults, molting their skins several times during this process, but not passing through any distinct pupal stage, and never spinning cocoons or forming a chrysalis. The adults vary in size, from $\frac{1}{20}$ to $\frac{1}{4}$, and rarely $\frac{1}{2}$, inch in length. They are all good jumpers or hoppers, as their common name implies. The adults are winged, but use their legs to a large extent in jumping from one part of the plant to another. The general outline of their bodies is long and slender, and, as above stated, they vary greatly both in color and in shape.

Control Measures.—Leafhoppers are extremely difficult insects to control. Cutting and removing the crops from heavily infested clover and alfalfa fields is about the most effective method of control, as this drives out some of the leafhoppers and starves some of the young nymphs. Immediately after cutting, large numbers of leafhoppers can be caught by running a hopperdozer over the infested field; or this machine may be used on the growing crops. It is most effective when the back and sides of the machine have been thoroughly coated with some sticky material such as tree tanglefoot that will catch the hoppers as they fly against it.

FIG. 265.—Adult of clover stem borer, *Languria mozardi* Latrielle, about eight times natural size. (*From Ill. State Nat. Hist. Sur.*)

References.—*Jour. Agr. Research*, Vol. 17, No. 6, pp. 399–404, 1927; *Annals Ent. Soc. Am.*, Vol. 16, p. 363, 1923; *U. S. Dept. Agr. Farmers' Bull.* 737, 1916.

CLOVER STEM BORER[1]

Importance and Type of Injury.—The clover stem borer generally causes but little damage. It is very generally distributed and more abundant than is usually supposed. Infested plants show a slight enlargement or cracking open of the stem, the latter injury being especially true in the case of sweet clover. The pith of the infested plant is eaten out and the stem occasionally so weakened that it breaks off. Usually, however, the plant grows in about a normal manner, and the presence of the insect is not suspected unless a careful examination of the stem is made.

Plants Attacked.—The insect feeds on clover, alfalfa, timothy, sweet clover, mammoth clover, daisy, yarrow, wild lettuce, and many other weeds and some cultivated plants.

Distribution.—This insect is generally distributed east of the Rocky Mountains and is recorded from Arizona. It is probably more abundant in the southern part of the country, although it is very common in the mid-western states.

[1] *Languria mozardi* Latrielle, Order Coleoptera, Family Erotylidæ.

Life History, Appearance, and Habits. The insect passes the winter as a slender, metallic-blue beetle with a shining red head and prothorax. It is a little over $\frac{1}{4}$ inch long, and is really a very pretty insect, the conspicuous coloring giving it a striking appearance (Fig. 265). The insects hibernate in trash around the clover fields. In the spring, the females lay their yellow eggs in the stems of the plants on which they feed. These eggs hatch in a few days and the young larvæ bore into the stems, feeding on the pith (Fig. 266). They grow rather slowly, most of them completing their growth by the latter part of August, pupating in the stems, and emerging as beetles during that month and September. A few larvæ have been found in stems of their food plants during the winter, and it is possible that some of the insects survive the winter in this stage.

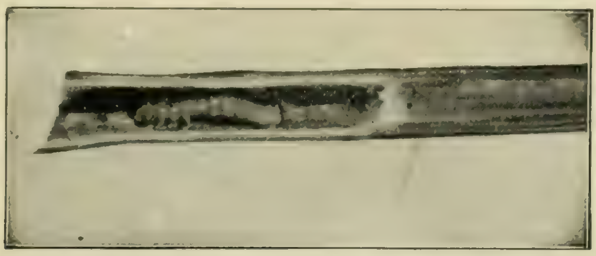


Fig. 266.—Clover stem borer, larva, in its burrow in clover stem; twice natural size. (*From Ill. State Nat. Hist. Sur.*)

Control Measures.—The ordinary practice of cutting two crops of clover each season serves to keep down the numbers of this insect, by cutting the infested stems when the larvæ are so small that they cannot complete their growth, and die within the drying hay. The insect is becoming more abundant in sweet clover grown for seed where the plants are not cut until late in the summer, and it is possible that it may become a rather serious pest of this plant.

References.—*Ill. Agr. Exp. Sta. Bull.* 134, 1909; *U. S. Dept. Agr. Dept. Bull.* 889, 1920.

Clover Seed Chalcid[1]

Importance and Type of Injury.—This is one of the most important insect pests of alfalfa and clover seed, but has no effect on the production of hay from these crops. Infested plants have little to distinguish them from those that are uninfested. A close examination of the seeds, however, will show many of them broken or cracked open. Threshed seed will show many empty shells of the seed, or parts of such shells. Very small, white, maggot-like larvæ develop in the infested seeds, eating the contents (Fig. 267, *e*). In some sections this insect has made the growing of clover and alfalfa seed unprofitable.

Plants Attacked.—The insect attacks nearly all the clovers and alfalfa.

Distribution.—General over the United States and southern Canada.

Life History, Appearance, and Habits.—The insect passes the winter in the full-grown larval stage (Fig. 267, *b*) inside the infested seeds on the surface of the ground. Occasionally the insect may pupate in the fall and remain inside the seed in this stage. The adult insects begin emerg-

[1] *Bruchophagus funebris* Howard, Order Hymenoptera, Family Chalcididæ.

ing during the late spring, usually the latter part of May in the latitude of central Illinois. Adults of the first generation occur in great numbers during the first part of June. The adult insect (Fig. 267, *a*) is a very active little wasp-like creature, jet metallic black in color, with legs of a dark brownish color, and tarsal claws of a light yellowish-brown. They are so small, being only about $\frac{1}{15}$ inch in length, that one has great difficulty in seeing them in the field, and will never suspect their numbers unless they are collected in a fine-mesh net. The female insects lay their eggs in clover in which the seed has formed, but has not yet hardened. The egg is pushed inside the soft seed, and hatches into a white, footless,

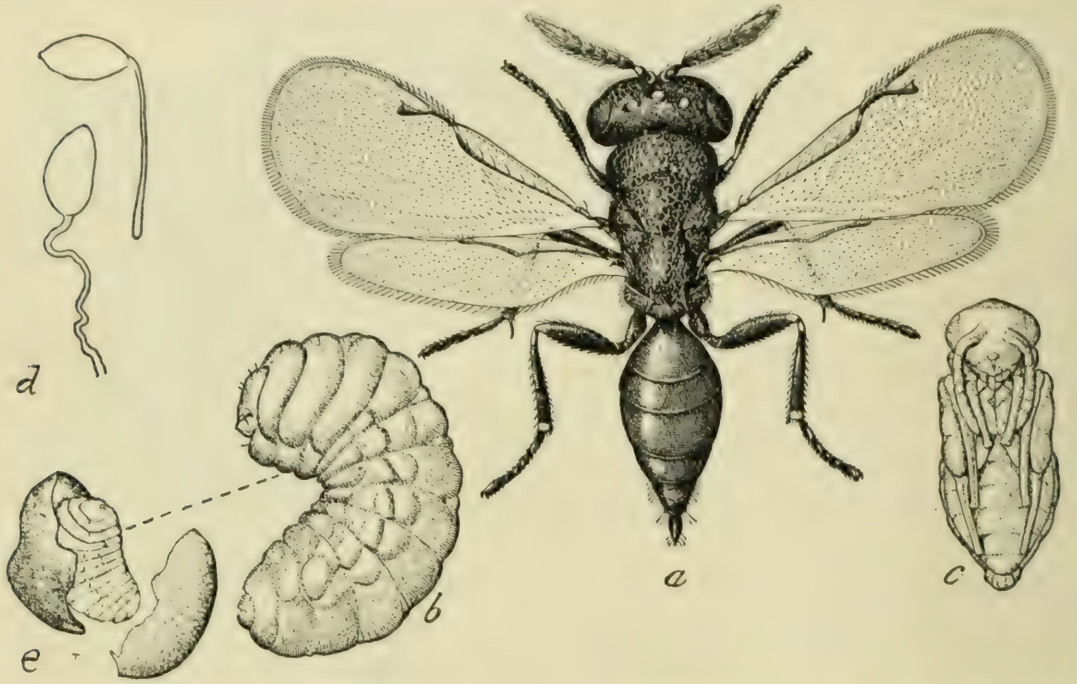


FIG. 267.—Clover seed chalcid, *a*, adult; *b*, larva; *c*, pupa; *d*, egg; *e*, larva in broken seed; all greatly enlarged. (*a, b, c, from U. S. D. A. Farmers' Bull.* 636; *d, from Ill. State. Nat. Hist. Sur.; e, from Ohio State University.*)

maggot-like larva that consumes the entire inside of the seed, leaving only a thin outer shell. The larvæ complete their growth in 2 weeks or more, depending on the weather. As the adult insects continue to emerge over a long period, the first-generation larvæ occur over a correspondingly long period. Upon becoming full-grown, they pupate inside the seed, either in the head or in seed which has dropped to the surface of the ground and emerge about midsummer as adults. These adults lay the eggs for a second generation, and in the South a third generation occurs late in the season. The generations overlap, however, so that the insects are present in all stages in the field practically at all times from the first of June until September.

Control Measures.—This insect has been found extremely difficult to control. When the seed crop is known to be heavily infested, as indi-

cated by the presence of many adult wasps about the heads, many of the insects can be killed by early cutting the crop and removing the hay from the field before the seed has had time to mature. If this is generally practiced in a community, and volunteer red clover, alfalfa, and bur clover is kept down, the numbers of the insect may be somewhat reduced. Destruction of chaff and screenings left in the hulling operation is important in preventing the emergence of adults the following spring. However, at present, we are nearly dependent on the natural enemies of the insect to hold it in check, as no really effective control measure has been developed.

References.—*U. S. Dept. Agr. Farmers' Bull.* 636, 1914; and 693, 1915; *U. S. Dept. Agr. Dept. Bull.* 812, 1920; *Ill. Agr. Exp. Sta. Bull.* 134, 1909.

Clover-head Caterpillar[1]

Importance and Type of Injury.—Clover heads infested by the clover-head caterpillar present somewhat the same appearance as those infested by the clover seed midge. The head is usually irregular in appearance and will have the flowers opening on only one side of the head. Such heads are often pink on one side and green on the other. An examination of the infested heads will show a small, somewhat hairy caterpillar feeding on the seeds at the base of the clover florets, preventing them from opening (Fig. 268, *A*). These caterpillars are very small, being only about ¼ inch long when full-grown.

Plants Attacked.—The insect feeds mainly in the heads of red clover, but has also been found on white clover, alsike clover, and mammoth clover. It also attacks the leaves of these plants when no heads are present.

Distribution.—The clover-head caterpillar is distributed generally over the eastern part of the United States and southern Canada.

Life History, Appearance, and Habits.—The insect passes the winter in both the larval and pupal stages, both being found under trash and around clover fields. Pupation occurs inside of small silken cocoons about ⅓ inch in length. These are very hard to find because of the dirt which is usually attached to the outside of them. The overwintering larvæ pupate in the spring, and from these, and the overwintering pupæ, the moths begin emerging just about the time that red clover is starting to come into bloom. They are small dark-brown moths about ¼ inch long. The wing margins are marked with six or seven short dashes, silvery-white in color. The marks on the inner margins form a double crescent when the wings are folded (Fig. 268, *B*). They lay their eggs on the leaves, stems, and heads of clover. The young larvæ hatching

[1] *Laspeyresia interstinctana* Clemens, Order Lepidoptera, Family Olethreutidæ.

from these eggs feed on the clover leaves, or more usually work their way into the green clover heads, feeding at the base of the florets and destroying from half to all of the florets in a head. The larvae are said not to destroy the hardened seed, but eat the green, soft, newly formed seeds. They complete their growth in 4 or 5 weeks, being about ¼ inch long and of a greenish to greenish-white color (Fig. 268, *C*). They spin their cocoons either in the head, or about the base of the clover plants and

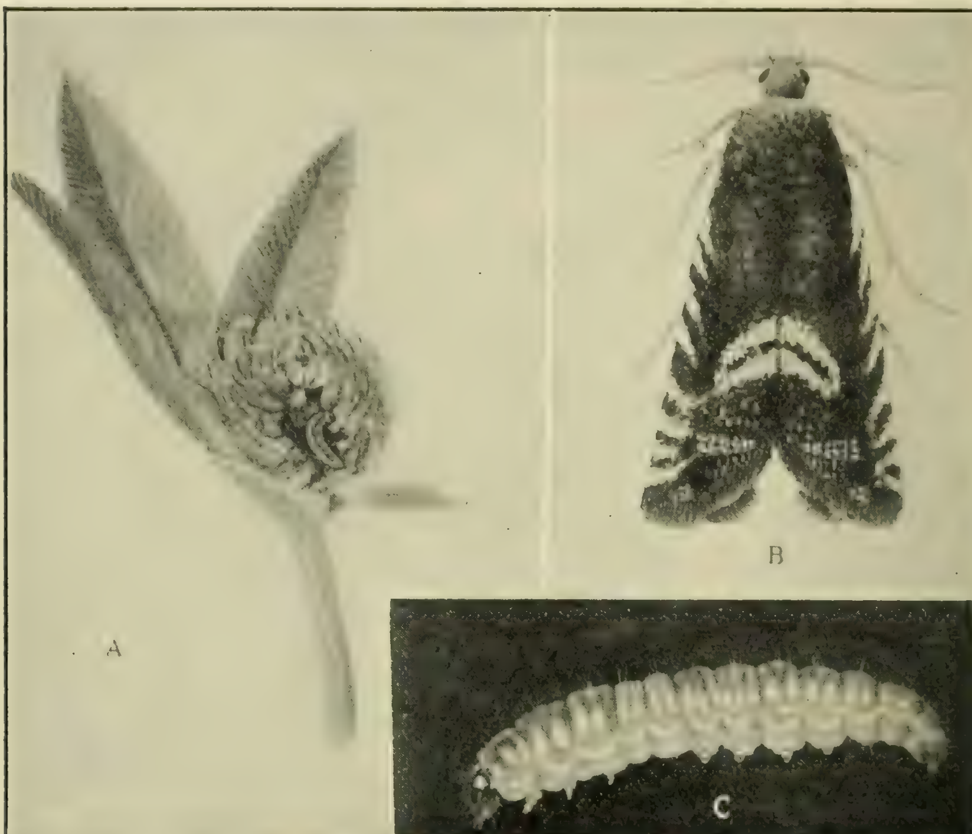


Fig. 268.—Clover-head caterpillar, *Laspeyresia interstinctana* Clemens. *A*, larva at work in head of red clover, slightly enlarged; *B*, adult, with wings folded, about eight times natural size; *C*, larva, side view, about eight times natural size. (*From Ill. State Nat. Hist. Sur.*)

change inside the cocoons to the brown pupal stage, which lasts about 15 to 20 days. The moths of the second generation emerge about midsummer. A third generation occurs throughout the entire southern part of the insect's range.

Control Measures.—The only measures that have been found at all practical for reducing the numbers of these insects are the same as those given for the control of the clover seed midge. Rotation of crops is also of some benefit in keeping down the numbers of this insect.

References.—N. Y. (Cornell) Agr. Exp. Sta. Bull. 428, 1923; *Ill. Agr. Exp. Sta. Bull.* 134, 1909.

Clover Seed Midge[1]

Importance and Type of Injury.—The clover seed midge, if very abundant, is capable of practically destroying the red-clover-seed crop. Its presence is indicated by the failure of many of the clover florets to open (Fig. 269, *May* and *June*). Where many maggots are present in the head, it will present a stunted appearance with irregular bloom, most of the head remaining green, the florets never opening. Infested seed presents a shriveled appearance, or scarcely forms within the base of the clover head. The insect has no effect on the production of clover for a hay crop.

Plants Attacked.—Red-clover seed is apparently the favorite food of this insect. It has been found in small numbers in alsike, mammoth, and sweet clover, but is of no importance on these crops.

Distribution.—The insect occurs generally throughout the United States from the East to the Pactific Coast; also in the southern part of Canada.

Life History, Appearance, and Habits.—The clover seed midge passes the winter in the larval stage inside a frail silken cocoon which is spun on, or shortly below, the surface of the ground (Fig. 269, *September*). Occasionally the larvæ will crawl under trash and not spin a cocoon. In this stage, the insect is about $\frac{1}{20}$ of an inch in length, and of a reddish-pink color. In early spring, the larvæ change inside the cocoons to the pupal stage and emerge during April and May as very small, fragile, delicate-winged flies. These flies are of a gray, dusty color with a bright-red abdomen which is especially noticeable in the female. The female is equipped with a long ovipositor equal in length to her body. With this, she deposits her eggs in the young clover heads just as they are appearing from the buds (Fig. 269, *May*). The pale-yellow eggs are attached singly or in clusters to the hairs about the calyx of the clover blossoms, each female laying about 100 eggs. The eggs hatch in from 3 to 5 days, and the young maggots work their way to the top of the flowers, and down inside the unopened petals. Here they feed by sucking the sap and thus destroy the flower and prevent the formation of seed. Upon becoming full-grown, the larvæ drop to the ground, generally during periods of rain (Fig. 269, *June*). They work their way below the surface, and there change inside their cocoons to the pupal stage. The first of the summer generation adults usually appear during the first part of July. They lay their eggs in the second-crop clover, and from these come the overwintering maggots. In the southern part of the country, a third generation is produced.

Control Measures.—When this insect alone is causing serious damge to clover seed, most of the injury may be prevented by cutting the clover a

[1] *Dasyneura leguminicola* Lintner, Order Diptera, Family Cecidomyiidæ.

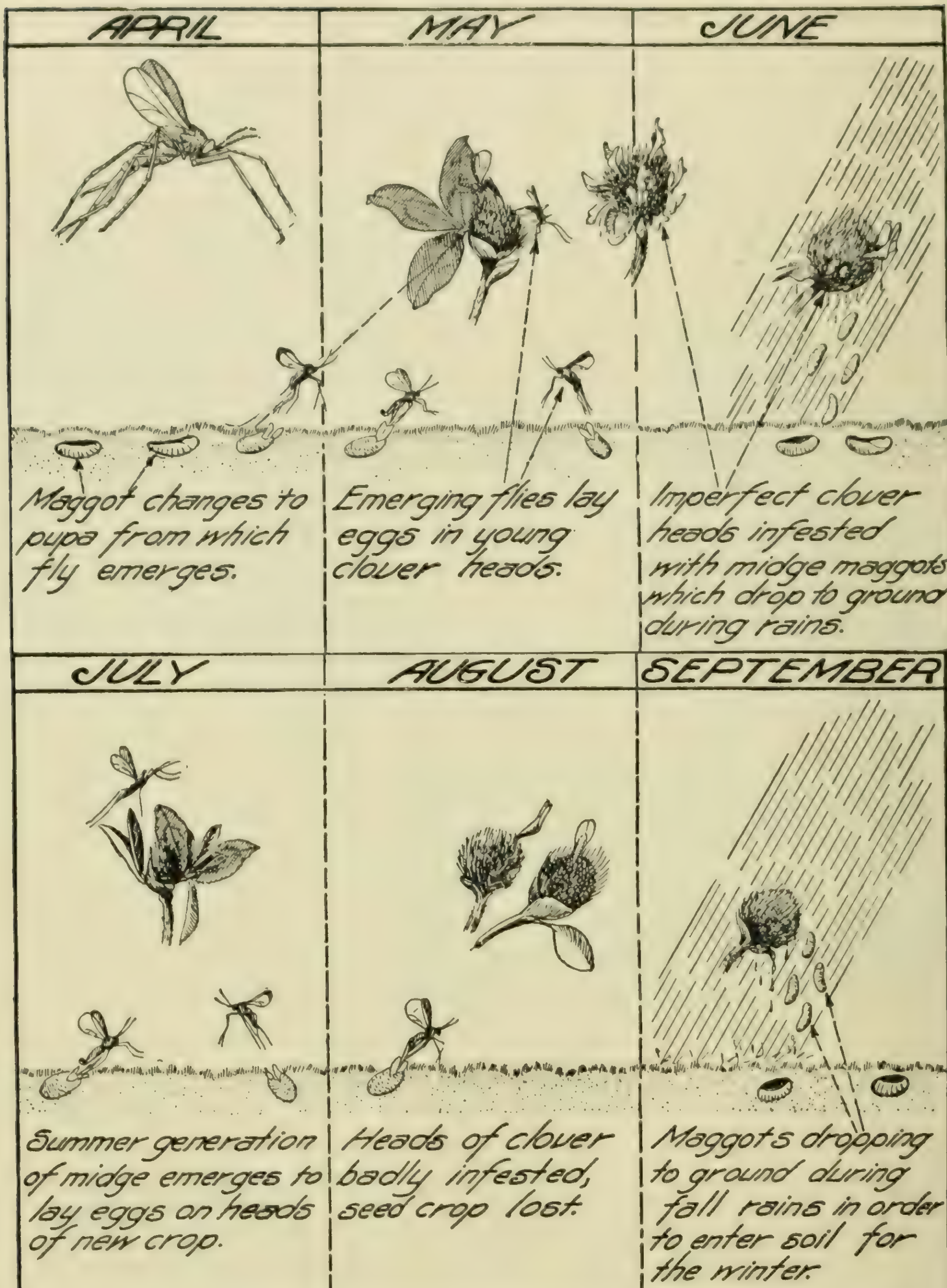


FIG. 269.—Diagram showing seasonal history of the clover seed midge, *Dasyneura leguminicola* Lintner. (*From U. S. D. A. Farmers' Bull.* 971.)

little before the uninjured heads have come into full bloom, and removing the hay from the field as soon as it is dry. This is a most effective control measure, as the cutting at this time will kill practically all of the young midge larvæ within the clover heads. The insect may also be controlled to some extent by clipping clover about 2 weeks before any of the heads show the bloom, and again about 1 month later. This brings the first-crop clover into bloom before the summer-generation midges have emerged. These measures apply mainly to the control of the clover seed midge and also to the clover-head caterpillar. Where several other clover insects are present, however, this practice may not be found to give the best production of seed.

References.—Ore. Agr. Exp. Sta. Bull. 203, 1917; *Ill. Agr. Exp. Sta. Bull.* 134, 1909; *U. S. Dept. Agr. Farmers' Bull.* 971, 1918.

B. SOYBEAN AND COWPEA INSECTS[1]

Soybeans and cowpeas have been, on the whole, more free from serious insect injury than most of the field crops. Grasshoppers are probably the worst insect pests of these crops, and in years when they are abundant, may seriously damage, or nearly destroy, soybean fields. They may be controlled by the same methods as those given for the control of these pests on corn; see page 330. The poison-bran bait, however, should be applied to adjoining fields to kill the hoppers before they enter the soybeans, as they seldom originate in these fields, but migrate into them from adjoining fields. If the poison bait is applied in the soybean fields, it falls between the plants where the ground is heavily shaded, and very little of it is eaten.

The green clover worm (see page 395) has, during a few seasons, proved to be a very destructive pest of soybeans and cowpeas in the southern states. It may be controlled on these crops by dusting with calcium arsenate, at the rate of 5 to 7 pounds per acre, applying the material with a cotton duster, or a field-crop duster. In most years, the insect is of no importance on these crops (see *N. Car. Agr. Ext. Circ.* 105, 1920).

The clover root curculio, may completely destroy soybeans if they are planted on spring-broken clover sod. The adult beetles of the curculio attack the soybeans as they first come up and eat off the plants as fast as they appear through the ground. No injury has been reported to these crops when planted on clover-sod ground, plowed in the fall or early winter. Where soybeans are to follow spring-broken clover sod, it should be well harrowed and planting delayed as late as possible. (For full description of this insect, see page 382.)

In the southern states the cowpea is sometimes badly damaged by the caterpillars of the corn earworm or cotton bollworm. There is no

[1] See *Ohio Agr. Exp. Sta. Bull.* 366, 1923.

effective method of controlling this insect on cowpeas. Damage occurs only in scattered seasons during periods of their greatest abundance.

The cowpea weevil,[1] the four-spotted bean weevil[2] and some other weevils often are very destructive to stored cowpea seed. The insects deposit their eggs in the cowpeas in the field, the infestation originating from infested seed, or from scattered cowpeas remaining in the field from the previous year. (The control of these insects is given under Stored Grain Insects, p. 764.)

The striped blister beetle (see p. 474) is sometimes a serious pest in soybeans (see *U. S. Dept. Agr. Leaflet* 12, 1927). The spotted cucumber beetle is sometimes abundant on soybeans and cowpeas, but never sufficiently injurious to warrant taking special control measures. Several aphids also attack these crops, but are not of special importance. Leafhoppers are often abundant, especially in fields of soybeans, and occasionally cause some injury to the leaves.

The Mexican bean beetle[3] (see Garden Insects, p. 451) has caused some injury to soybeans and cowpeas where these crops were grown in close proximity to heavily infested garden beans. It has not been of importance in the areas where soybeans or cowpeas are grown alone as field crops.

[1] *Mylabris chinensis* (Linné), Order Coleoptera, Family Mylabridæ.

[2] *Mylabris quadrimaculatus* Fabricius.

[3] *Epilachna corrupta* Mulsant, Order Coleoptera, Family Coccinellidæ.

CHAPTER XIV

COTTON INSECTS

FIELD KEY FOR THE IDENTIFICATION OF INSECTS INJURING COTTON

A. *Insects that attack the squares and bolls:*

1. Squares flaring, and either falling to the ground, or hanging withered and dry on the plant. Squares and bolls with wart-like scars, covering punctures which are about the diameter of a pin. Inside of bolls decayed and soiled. White, curved-bodied, brown-headed, legless grubs, up to ½ inch long, feed in the squares and bolls destroying the unopened buds, lint, and seed. Hard-shelled, grayish to brown, long-legged beetles, averaging ¼ inch long, with a slender snout half as long as the body, puncture squares and bolls to feed and lay eggs in them. *Cotton boll weevil*, page 411.

2. Flowers fail to open, squares fall, and bolls are eaten out but not decayed-looking. A pinkish-white, brown-headed caterpillar up to ½ inch long, found inside the fruits or seeds; easily distinguished from *A*, 1 by having eight pairs of legs and prolegs. Larvæ often bore inside of the seeds, and web two seeds together, so that "double seeds" are found when the cotton is ginned. Distinguished from other caterpillars by having four teeth on the mandibles and the crochets on the prolegs horseshoe shaped. Restricted to western Texas, New Mexico, and Arizona. *Pink bollworm*, page 418.

3. Light to dark green, pinkish or nearly black, more or less striped caterpillars, up to 1¾ inches long, bore into squares and bolls and eat out the interior. The worms have three pairs of slender legs behind the head, and five pairs of fleshy prolegs, and the skin is rough and thorny appearing under a lens. *Cotton bollworm* or *corn earworm*, page 416.

4. Squares eaten out as in *A*, 3 by bright green, oval, distinctly flattened caterpillars, covered with short velvety hairs, and with the head drawn under the front of the body; not exceeding ¾ inch in length. *Cotton-square borer, Uranotes melinus* Hübner, (see Sanderson and Peairs, "Insect Pests," p. 232, 1921).

5. The lint, especially of long-staple cotton, is stained an indelible yellow color by flattened, rather narrow, long-legged bugs of various sizes up to ⅗ inch long, with head and prothorax bright red and the rest of the body dark brown, crossed with light-yellow lines. The bugs puncture the seeds in the developing bolls and cause a juice to exude that stains the lint. *Cotton stainer, Dysdercus suturellus* Herrich-Schaeffer (see *U. S. Dept. Agr. Bur. Entomol. Circ.* 149, 1912).

6. Squares and young bolls drop, shrivel or decay; small, round, blackened spots appearing on their surface where they have been punctured by sap-sucking bugs. *Cotton-leaf bug, stink bugs and leaf-footed plant bugs* (see *U. S. Dept. Agr. Farmers' Bull.* 223, 1905).

7. Small squares shed, buds blasted, and growth stunted; resulting in shortening of internodes and development of an excessive growth of branches close together, with deformed leaves, on young plants; and an excessively tall, whip-like growth of the main stem and a suppression of fruiting branches on older cotton. Small greenish bugs from 1/25 to 1/8 inch in length, with scarlet eyes, cluster on the growing tips. *Cotton fleahopper*, page 421.

B. Insects that chew the foliage, often stripping the leaves:

1. Cotton sometimes seriously defoliated, especially in wet seasons, by slender, green, black-and-white-striped caterpillars, with four black dots on each segment above, and ranging up to 1½ inches long. They crawl with a slightly looping movement and feed only on cotton. *Cotton leafworm,* page 416.

2. Cotton, along with most other plants, defoliated by tan or green to nearly black caterpillars with three yellow hair lines down the back and a wider one on the side that is splotched with red. Body covered with fine scattered hairs arising from black tubercles, and a prominent inverted *Y* on the front of the head. *Fall army worm,* page 435.

3. Foliage devoured by very hairy or woolly caterpillars, up to 2 inches long, black-bodied and covered with long black and red hairs. *Salt-marsh caterpillars* (see *U. S. Dept. Agr. Farmers' Bull.* 223, 1905).

4. Pieces of the leaves cut off and carried to their nests in the soil by reddish-brown ants varying from 1/12 to 1/3 inch in length. *Leaf-cutting ant* (see *U. S. Dept. Agr. Bur. Entomol. Circ.* 148, 1912).

5. Large and small, lubberly grasshoppers often invade cotton from near-by waste lands and defoliate the plants. *Lubber grasshoppers, differential grasshoppers* and others, page 327.

C. Insects that suck the sap of the leaves or stems:

1. Leaves of cotton curled or dwarfed; the undersides thickly dotted with small, winged or wingless, tan, brown, green, or black plant lice of various sizes, which suck the sap. *Melon aphid* or *cotton aphid,* page 464.

2. During hot weather the leaves of cotton become blotched with large irregular areas of reddish brown so that entire patches of varying size in the fields look red. Undersides of such leaves, when examined under a lens, are seen to be swarming with minute, pale greenish to reddish, six- or eight-legged mites. *Red spider,* page 448.

D. Insects that bore or tunnel in the stalks or puncture and split them:

1. Caterpillars, up to 1½ inches long, prominently striped with brown and white in front and behind, but with a large, grayish-brown "bruised-looking" area in front of the middle, burrow through the heart of the stem, killing the terminals. Especially bad around weedy margins of fields in early summer. Stripes disappear when caterpillars become full grown. *Common stalk borer,* page 337.

2. Cotton stalks in the fall of the year, are punctured and may be split by rows of round holes of the diameter of a pin and with an elongate curved white egg within. No injury to cotton. *Tree crickets,* page 637.

E. Insects that cut off and devour the young plants or seedlings:

1. Young plants cut in two at or near the surface of the soil, or the leaves eaten, at night. Plump, dirty-looking caterpillars, of various shades and markings of green, brown, and black, up to 1½ inches long, found in daytime in the soil. Often curl the body when disturbed. *Cutworms,* page 321.

2. Cotton in newly broken fields, or fields that were very grassy the year preceding, attacked while small by swarms of robust, long-legged, grayish or brown beetles, ½ to 1 inch long, that lack the underwings and cannot fly. They feed in late afternoon and at dusk, and may eat off the plants over a large field. *Wingless May beetles* or *June bugs* (see *U. S. Dept. Agr. Farmers' Bull.* 223, 1905).

3. Dark-brown to black, humpbacked beetles, nearly ¼ inch long, with a slender snout one-third as long as the body, bent down between the legs, appear during early summer in fields that were in cowpeas the previous year, and eat small holes in leaves or tender parts of stem. *Cowpea-pod weevil* (see *N. C. Dept. Agr. Bull.* Vol. 29, No. 6).

4. Many-legged, hard-shelled crayfish, with a pair of pincher legs in front, crawl out of burrows in wet soil and devour the plants. Not insects but crustacea. *Crayfish* or *crawfish,* page 422.

F. Insects that attack the roots, below ground:

1. Seeds fail to sprout or plant dies when small. Slick, whitish, slender, cylindrical worms up to 1 inch long, with six small legs behind the head, are found in the soil or eating into the seeds and roots. *Corn* and *cotton wireworm* (*Horistonotus uhleri* Horn) (see *S. C. Agr. Exp. Sta. Bull.* 180, 1914).

2. Seedlings weak, yellowish in color. Many small brown ants tunneling in the soil about the roots and caring for bluish-green, wingless plant lice or aphids about the size of pinheads, that cluster on the roots and suck the sap. *Corn root aphid* and *corn field ant* page 314.

Cotton Boll Weevil[1]

Importance and Type of Injury.—No insect pest in all the world has gained greater notoriety than the cotton-boll weevil. Very careful data have been collected as to the direct loss in production of seed and lint due to this pest. The most recent estimates place the current loss at 3,000,000 to 5,000,000 bales of cotton a year, or from 20 to 40 per cent of the normal production. This loss amounts to from $200,000,000 to $300,000,000 a year. It seems safe to say, therefore, that the total loss inflicted upon the cotton interests of the United States during the first 35 years of the boll weevil's invasion has been between $3,000,000,000 and $4,000,000,000. In addition to this direct loss, there have been enormous financial losses due to depreciated land values, the abandonment of cotton growing, the closing down of cotton gins and oil mills, the interruption of railroad, bank and mercantile business, and many other economic disturbances in territory where the boll weevil has appeared. It should not be supposed that the cotton farmer sustains all of the loss. On the contrary, it is borne chiefly by the users of cotton goods. The price of cotton lint has advanced from 6 to 8 cents a pound, before 1915, to 25 to 40 cents at pound since that time. Dr. W. E. Hinds estimates that each person in the United States pays $10 a year more for cotton goods than he would if the boll weevil were not present.

The injury is caused by the adult weevils and their young or grubs. The adults (Fig. 270, *c*) puncture the squares and bolls by chewing into them with their long slender bills to feed on the tissues inside and to lay their eggs in the holes. This causes the squares to flare (*b*) and either drop off or hang withered and dry (*a*). The grubs that hatch from the eggs feed inside the squares and bolls, destroying the developing flower so that it fails to bloom or else develops seeds with little fiber. A good indication of the importance of this feeding is the fact that where it is prevented by poisoning the weevils, gains of from 500 to 1,000 pounds of seed cotton per acre are often secured, the average gain being 300 to 400 pounds per acre.

[1] *Anthonomus grandis* Boheman, Order Coleoptera, Family Curculionidæ.

Food Plants.—This pest feeds almost exclusively on cotton, but has been known to feed also on okra and hibiscus. A variety of the weevil[1] in Arizona feeds on a wild cotton plant.[2] This variety also attacks cultivated cotton.

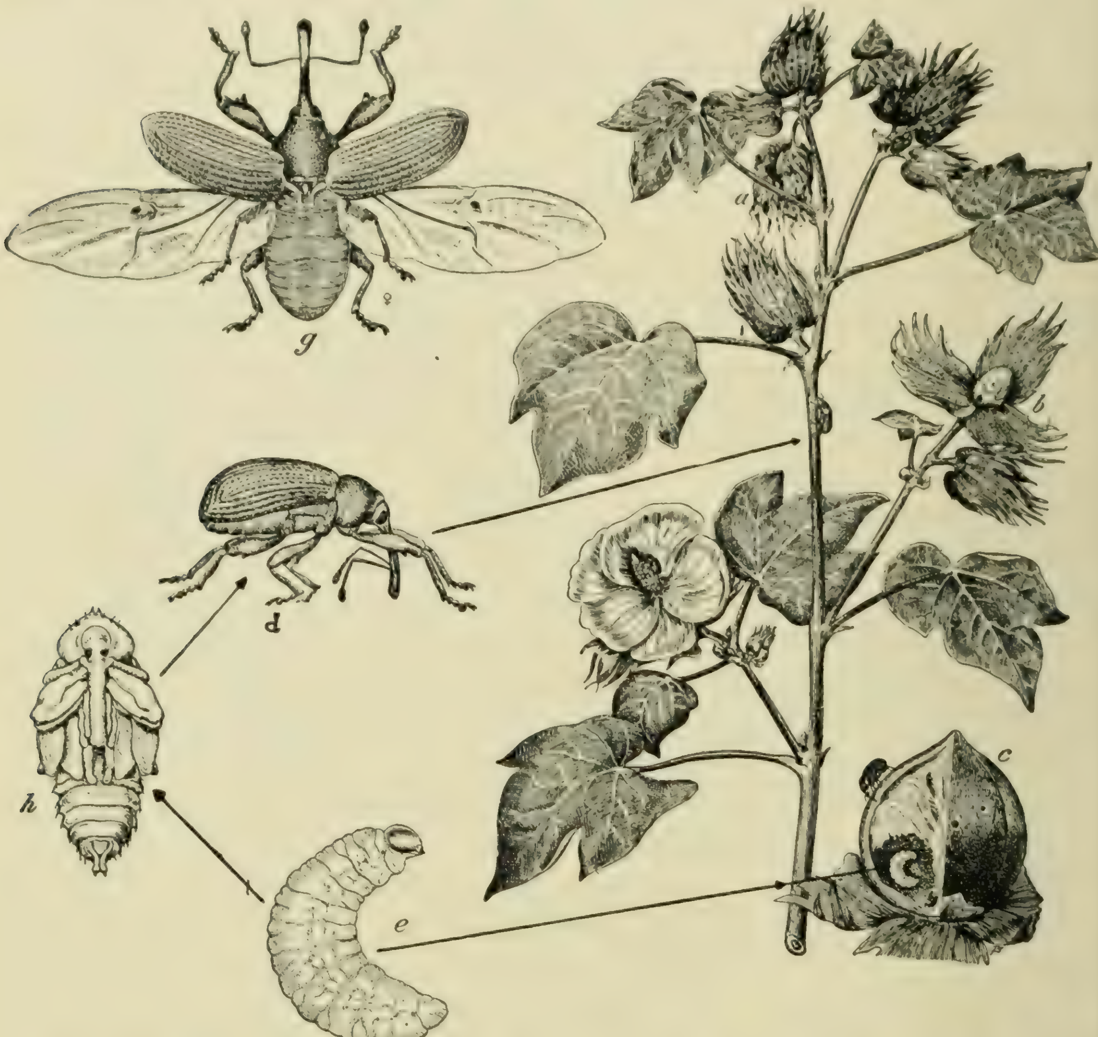


FIG. 270.—The cotton boll weevil, *Anthonomus grandis* Boheman. On the right a cotton plant attacked by the boll weevil, showing at *a*, a hanging dry infested square; at *b*, a flared square with weevil punctures; at *c*, a cotton boll sectioned to show attacking weevil and larva in its cell; *g*, adult female with wings spread as in flight; *d*, adult from the side; *h*, pupa ventral view and *e*, larva. (*Rearranged from U. S. D. A.*)

Distribution.—The cotton boll weevil is not a native of the United States. Its original home was in Mexico or Central America. Little was known about it previous to 1892, when it first appeared in southernmost Texas. From that date it has spread to the north and east, an average distance of about 60 miles a year (Fig. 271). An average of more than 20,000 square miles of new territory has been infested by the weevil in each of the 35 years since it crossed the Rio Grande River. It now

[1] *Anthonomus grandis thurberiæ* Pierce, Order Coleoptera, Family Curculionidæ.

[2] *Thurberia thespesioides.*

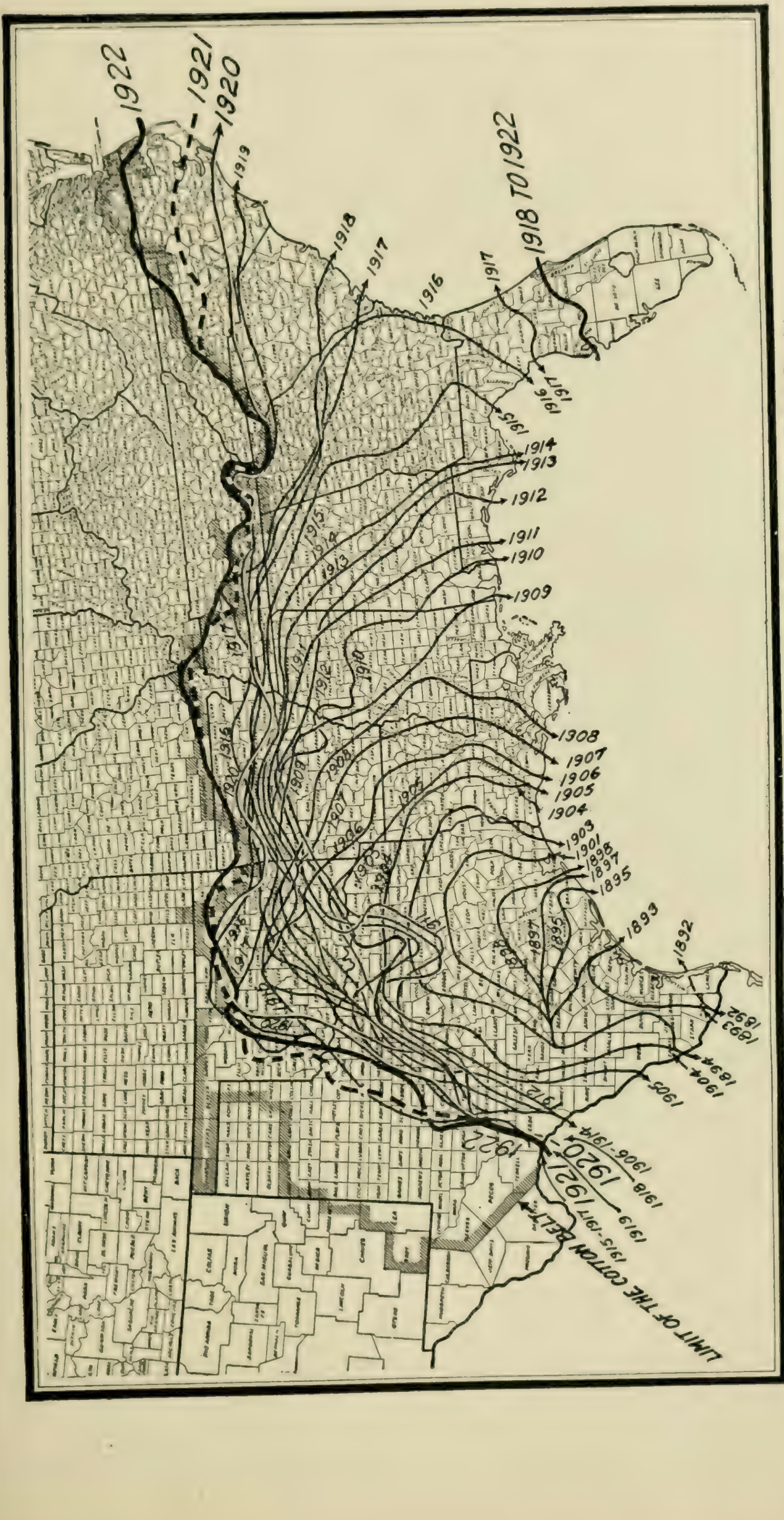


FIG. 271.—Map showing spread of cotton boll weevil. (*From U. S. D. A.*)

occupies more than 90 per cent of the cotton-growing territory in the United States. It also ranges southward throughout Mexico to Guatemala and Costa Rica and is known to occur in Cuba.

Life History, Appearance, and Habits.—The boll weevil winters chiefly in the adult stage in all kinds of shelter; under dead leaves and cotton stalks, under loose bark, about gins and barns, in woods, along fences, and in many other protected places. The adult beetle (Fig. 270, *d*, *g*) is a small, hard-shelled weevil, averaging about 1/4 inch long, of a yellowish, grayish, or brownish color, becoming nearly black with age. It has a slender snout, half as long as the body, and close-fitting, smooth wing covers with fine parallel lines and covered with short gray down or fuzz. The most characteristic feature about the boll weevil is the two spurs or teeth near the end of the front femur, the inner one being much longer than the other, and a single tooth on the middle femur.

From about the time early cotton is up (March), until early June, the adults straggle out of hibernation, feeding at first on the tender terminal growth of the plants. As soon as the blossom buds or "squares" appear, the weevils attack them, eating cavities into them and laying a single egg in each hole, and usually one egg to a square. Each female may lay from 100 to 300 eggs. Later in the season eggs are laid in the bolls, but the squares are always preferred. The egg hatches in 3 days to the grub or larva. The larva feeds and grows 1 or 2 weeks inside the square or boll, molting two or three times and becoming about 1/2 inch long. It is white, legless, curved-bodied, and much wrinkled, with brown head and mouth parts (Fig. 270, *e*). It never leaves the square or boll in which the egg was laid, but transforms to the pupa stage in the hollowed-out, dirty cavity formed by its feeding. The pupa stage (*h*) lasts 3 to 5 days or more, when the final change is made to the adult. The adults eat their way out of the squares or bolls, mate, and within 4 or 5 days may be laying eggs for a new generation. Since the life stages may be passed in from 15 to 25 days, it is apparent that there may be from two or three to as many as eight or ten generations in a single year. Late in the season, as cotton becomes mature (mid-August to early September), the weevils spread extensively, taking flights by short stages that may total 20 to 50 miles or more. The chief spread of the insect comes at this time. After heavy frosts the insects go into hibernation as already described.

Control Measures.—Because all of the developing stages of the weevil are spent inside the squares and bolls of the cotton plant and the adults insert their slender snouts below the surface to feed, this insect is one of the most difficult of all known pests to control. Successful control can be achieved only by a combination of measures, of which the following are the most important.

1. Fall Destruction of Plants in the Field.—When examination shows that nearly all of the squares in the field are being punctured by weevils,

the cotton should be harvested as soon as possible and the stalks plowed out, immediately collected together and burned or plowed under deeply. No more cotton can be made from punctured squares, and the prompt destruction of the plants prevents the maturing of thousands of late weevils, which are the chief ones to winter over. The destruction of the plants before the first killing frost, and fall plowing, will remove hibernating places and make possible the early planting of the next crop.

2. Making an Early Crop.—Since the weevils prefer squares in which to lay their eggs and such squares are doomed to make no cotton, it is of the greatest importance to get the blossoms past the square stage to the boll stage before weevils become abundant enough to damage many of them. The use of early-maturing varieties, planting as early as the seed bed can be thoroughly well prepared; enriching the soil by the use of legumes and commercial fertilizers; and frequent shallow cultivation not too close to the plants are important in making the early crop.

3. Dust Poisoning.—When the crop has been made by the best farming possible, it should be protected and further increased by poisoning the weevils with calcium arsenate. This will generally pay where the land normally yielded at least one-third to one-half bale per acre before the weevil invasion. An average gain of 300 to 400 pounds of seed cotton per acre is commonly secured where proper dusting is done. Proper dusting requires (*a*) the purchase of good machinery; (*b*) the use of calcium arsenate dust containing not less than 40 per cent total arsenic pentoxid, of which not more than three-fourths of 1 per cent is in water-soluble form, and of a density between 80 and 100 cubic inches per pound; (*c*) dusting at night or on calm humid days if ground machines are used; (*d*) making three or four applications at intervals of 4 days and using 5 to 7 pounds per acre; (*e*) delaying the first application until 10 to 15 out of 100 squares on the average are punctured by weevils.

Since about 1923, applying the poison by airplane has become very successful. Specially designed planes fly from 5 to 25 feet above the cotton tops at a speed of about 80 to 100 miles an hour. They discharge the calcium arsenate dust from special hoppers in a swath 200 to 250 feet wide and dust the cotton at a rate of 400 to 500 acres per hour. The work is done during the daytime and can be made more thorough than hand- or ground-machine dusting and requires only about two-thirds as much poison. The dust delivered from air planes sticks to the foliage better because of the electrical charge it carries. The total cost for airplane dusting averages about $1 per acre for each application.

(4) Pre-square Poisoning.—When the infestation as the very first squares appear on the plants amounts to more than 20 weevils per acre, a poison syrup or calcium-arsenate dust should be applied to the tips of every plant. The poison syrup is made by mixing 2 pounds of calcium-arsenate powder in ½ gallon of water, stirring to a white paste. Add 1 gallon of

good-grade table syrup and stir thoroughly. It may be applied with home-made mops or swabs.

References.—*U. S. Dept. Agr. Bur. Entomol. Bull.* 114 (U. S. Senate Document No. 305) 1912; *U. S. Dept. Agr. Farmers' Bull.* 1329, 1923; *Quar. Bull. State Plant Board of Fla.* VIII, 2, 1924; the publications of local experiment stations.

Cotton Bollworm or Corn Earworm[1]

This caterpillar which also attacks corn (see p. 350), tobacco, tomatoes (see p. 490), beans, vetch, alfalfa, and many garden plants and flowers, destroys the squares and bolls by eating into them. Unlike the boll weevil the parent stage is a moth that does no harm except to lay the eggs. The eggs are laid on the leaves and outside of squares. The caterpillars do not remain in one boll but bore out again and crawl from square to square, a single worm often destroying all of the fruits on a branch of the plant. The pupa stage is passed in the soil at a depth of 1 to 4 inches. The first two generations are usually passed on corn, tobacco, and other plants, and it is not until the third generation (August and later) that the bollworm becomes destructive to cotton.

On this account every effort should be put forth to make an early crop, as suggested for controlling the boll weevil. Since the insect winters in a helpless pupa stage in the soil, deep plowing and cultivating the soil in fall and winter is effective by turning up the pupæ and exposing them to natural enemies and to the weather. Dusting as for the boll weevil gives effective control for this insect also.

Cotton Leaf Worm[2]

Importance and Type of Injury.—Slender, greenish, looping worms, with black-and-white stripes and a number of small rounded black spots scattered over the body (Fig. 272, *B*) rag or strip the leaves of cotton, especially late in the season. Four of the black dots form a square on the back of each segment, and the last pair of prolegs stands out conspicuously behind the body. The adult moth sometimes causes injury to ripe peaches, grapes, and other fruits by lacerating them with spines on the end of its tongue. In this respect it is a striking exception to the rule that adults of Lepidoptera are not injurious.

Plants Attacked.—The larva feeds only on cotton. Adults sometimes feed destructively on ripe peaches, grapes, and other fruits.

Distribution.—Eastern United States from the Great Lakes southward into the tropics. More destructive in the Gulf States than farther north.

Life History, Appearance, and Habits.—This insect is not known to winter in the United States. It is a tropical insect, but frequently the

[1] *Heliothis obsoleta* Fabricius, Order Lepidoptera, Family Noctuidæ.

[2] *Alabama argillacea* Hübner, Order Lepidoptera, Family Noctuidæ.

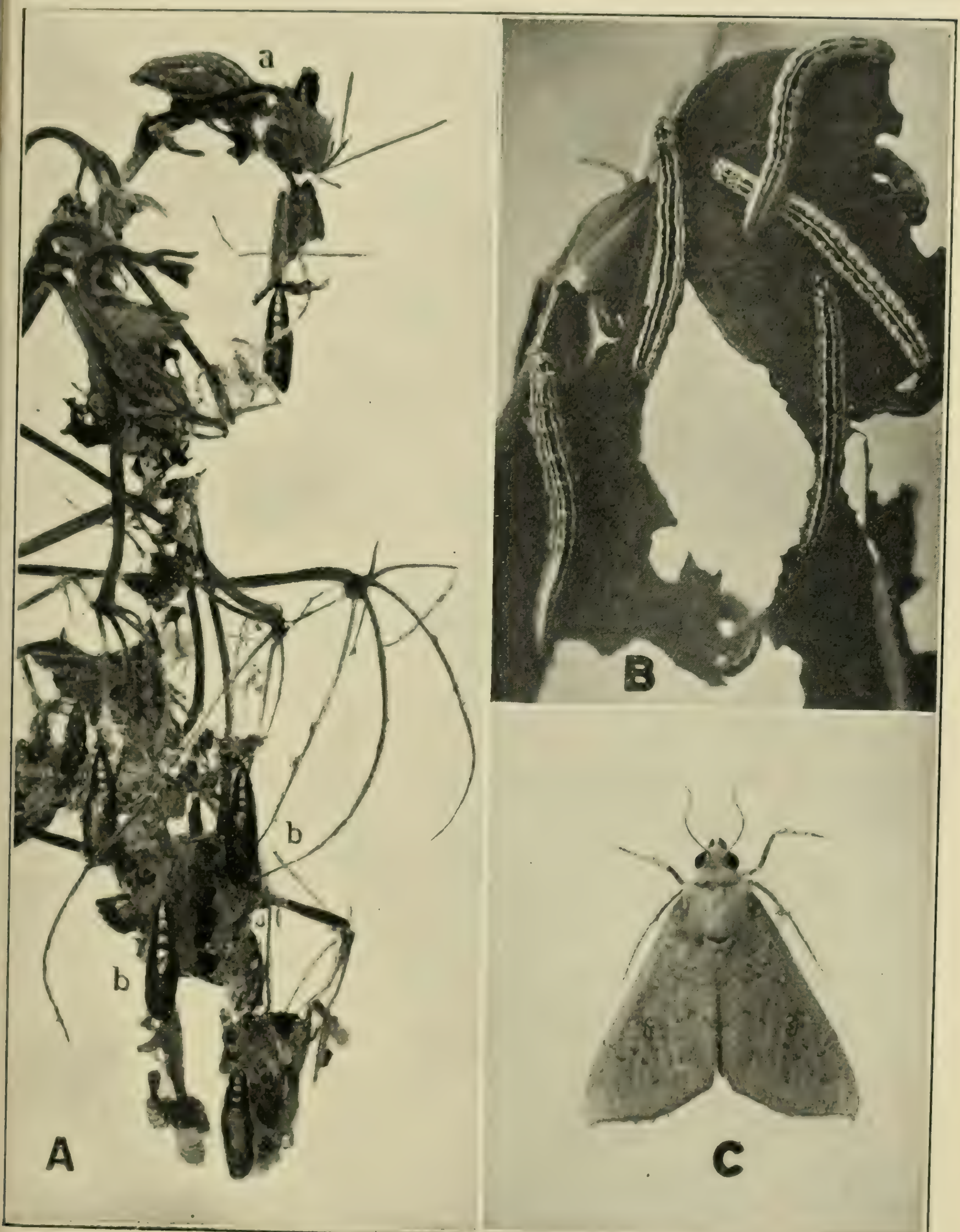


FIG. 272.—The cotton leaf worm, *Alabama argillacea* Hübner. *A*, larva, pupæ, and injury: note how the leaves have been stripped, the larva at *a*, and the pupæ attached by their posterior ends at *b,b* (*from U. S. D. A*). *B*, larvæ natural size, devouring foliage. *C*, adult female moth, enlarged one-half, in resting position. (*From Alabama Polytechnic Institute.*)

adult moths fly northward in great numbers as far as the Great Lakes, and even into Canada. The eggs are deposited on the underside of cotton leaves. The larvæ reach full size ($1\frac{1}{2}$ inches in length) in 2 to 3 weeks. They pupate on the plant, inside a fold of leaf or fastened by their tails to the foliage (Fig. 272, *A*). A generation is completed in about a month. There are from three to seven generations in the cotton belt, and the moths of each successive generation fly farther and farther to the north. The moths (Fig. 272, *C*), which measure about $1\frac{1}{4}$ inches from tip to tip of wing, are of an olive-tan color with three more or less prominent, wavy transverse bars on each front wing. All stages die out during the winter in the United States; the species surviving only in the tropics.

Control Measures.—Where poisoning for the boll weevil is practiced, this insect will not give trouble. If it appears early in the season, an application of calcium arsenate should be made. Late in the season the feeding of the leaf worm is considered a benefit in boll-weevil territory because it destroys the top growth which could not make cotton and which would sustain the boll weevil late in the fall. When the adults are troublesome in orchards it has been found possible to prevent much injury by applying a sulfur dust with a power duster. In small orchards or vineyards many of the moths may be killed by setting around the trees a few pans of crushed fruits poisoned with sodium arsenite, two teaspoonfuls to the gallon.

Cotton Aphid[1] or Melon Aphid

Almost as soon as cotton has put out leaves, small, soft-bodied, pale-green plant lice fly to them and start their families. In cool, wet seasons, when their own enemies cannot work against them so well, they may become abundant enough to stunt and deform the plants. Often, when the hot weather of summer comes on, they practically disappear. Spraying or dusting with nicotine may be used to destroy them, but the expense will seldom be justified. (See also p. 464.)

Corn Root Louse[2]

This root-feeding plant louse and its attendant ant are pests of cotton, which they attack just as they do corn in some parts of the cotton belt, especially in the Carolinas. The life history, descriptions, and control are discussed under corn insects (see p. 314).

Pink Bollworm[3]

Importance and Type of Injury.—The pink bollworm is considered one of the half-dozen most destructive insects in the world. Its attack

[1] *Aphis gossypii* Glover, Order Homoptera, Family Aphididæ.

[2] *Anuraphis maidi-radicis* Forbes, Order Homoptera, Family Aphididæ.

[3] *Pectinophora gossypiella* Saunders, Order Lepidoptera, Family Gelechiidæ.

causes the squares to fall or blossoms fail to open and, as the season advances, the bolls are rendered worthless by the feeding within them of a number of pinkish-white caterpillars, which very often eat into the seeds. The caterpillars range up to ½ inch in length, are cylindrical, and pinkish on the upper part. The lint fails to develop, or is so stunted as to be unpickable, and the yield of oil from the seed is greatly decreased. Double seeds (Fig. 274) are found when the cotton is ginned, two partly eaten seeds being fastened together. A loss of from one-fifth to one-half of the value of the crop is regularly suffered in infested areas, and the establishment of this pest throughout our cotton belt would doubtless result in "an annual loss of 20 to 40 per cent of the crop, or a money loss of several hundred million dollars annually" (Hunter).

Plants Attacked.—Cotton and rarely okra; and possibly hollyhock and other malvaceous plants.

Distribution.—The pest is believed to be a native of India, whence is has been carried by commerce to most of the other cotton-producing countries of the world. It is well established and a very destructive

FIG. 273.—Larva of the pink bollworm. About six times natural size. (*From U. S. D. A. Dept. Bull.* 1397.)

pest in nearly all of the cotton-growing countries of Asia, and adjacent islands, including Hawaii and the Philippines, in north, east and west Africa, in Australia, in Brazil, in the West Indies and in Mexico. It was brought to Mexico in 1911 in seed imported from Egypt, and in 1915 or 1916 was carried across the border into Texas in cotton lint and seed. Since its first discovery in Texas in 1917, it has been found at many points in Texas and near the border in New Mexico, and also in Louisiana. Since its first discovery in the United States, Congress has made appropriations averaging more than half a million dollars a year, to bring about its eradication. Two infestations in Louisiana and four in eastern Texas, one of them covering about seven counties, have apparently been completely exterminated. In extreme western Texas and New Mexico, the danger of continuous reinfestation from across the border has made the expensive extermination work inadvisable.

Life History, Appearance, and Habits.—The winter is passed in the larval stage (Fig. 273), the insect being curled up in a small cocoon either in stored seed (Fig. 274) or in the soil or in bolls in the field. Some of these larvæ are long-cycle, or resting, caterpillars that may remain in this stage as long as 2½ years. These are frequently found inside the seeds, and there is the greatest danger of spreading the insect to great

distances by shipping seed. Pupation takes place in the upper 2 inches of the soil or on the ground under trash or in the seeds or bolls. The pupa is not quite smooth but is covered with very short fine pubescence. In 1 to 3 weeks the small, dark-brown moths emerge. They measure about $\frac{3}{4}$ inch from tip to tip of wings, and somewhat resemble the common clothes moth. The wings are narrow, with a wide fringe, and are peculiarly pointed at the tip. The first segment of the antenna has five or six long stiff hairs, and the palps are long and curved. The moths are seldom seen, as they hide during the daytime.

The greenish-white eggs are scattered all over the cotton plant, but mostly on the bolls, from 1 to nearly 100 in a place, and hatch in 4 to

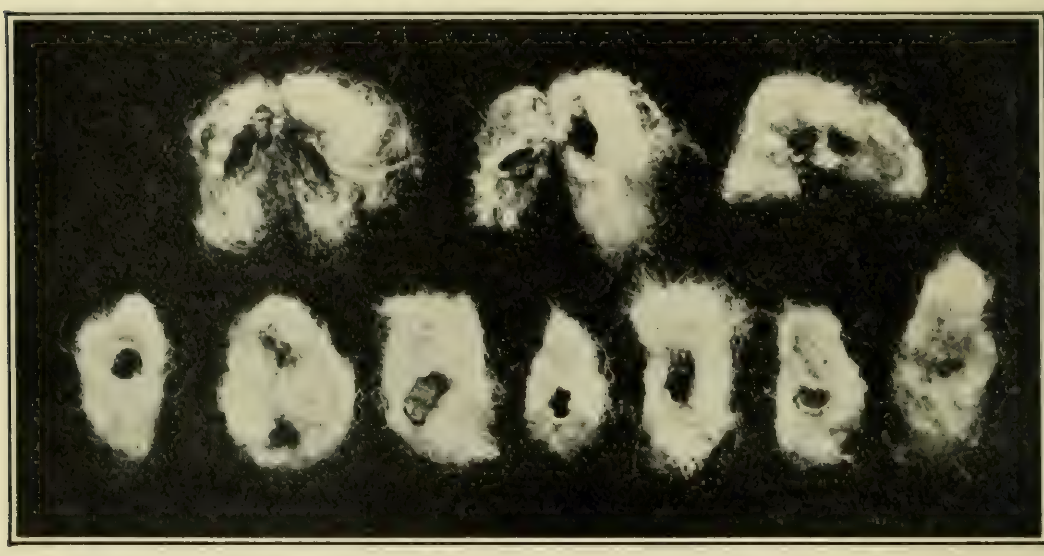


Fig. 274.—Cotton seeds containing pink bollworms opened to show the cells. Both single- and double-seeded cells are shown, the double-seeded ones being broken apart. (*From U. S. D. A. Dept. Bull.* 1397.)

12 days. The larvæ promptly drill into the squares and eat the developing flowers or into the bolls, where they consume both lint and seeds. After growing for 3 or 4 weeks, they may change to pupæ and form adults for a new generation, or may hang over as the resting larvæ. There are from four to six generations in a year.

Control Measures.—The worms can be killed in cotton seed by heating to 145° F., without injury to the seed. The cleaning and fumigating of gins, oil mills, warehouses and seeds with carbon bisulfide is important. Early maturity of the crop, followed by the burning of old stalks and bolls is the best farm practice. Careful application of arsenicals to the plants reduces the infestation materially, but no really satisfactory control for this serious pest has been discovered. Every effort is being made to prevent its spread over the cotton belt.

It has apparently been stamped out of the small areas in eastern Texas and Louisiana where it became established, by annual clean-ups

and by preventing the growth of cotton in the infested districts. Strict quarantines are in force to prevent continuous reinfestations from cotton seed carried across the border. On account of the difficulty of enforcing this absolutely, it has been proposed to establish a "no-cotton belt," 300 to 500 miles wide, along the Rio Grande in western Texas.

References.—*U. S. Dept. Agr. Dept. Bulls.* 1374 and 1397, 1926; *U. S. Dept. Agr. Dept. Bull.* 918, 1921; *Jour. Agr. Research*, Vol. 9, pp. 343–370, 1917.

Cotton Fleahopper[1]

Importance and Type of Injury.—In scattered areas throughout the cotton belt, this small green sucking bug has sporadically caused serious losses by sucking the sap from the very small squares and other terminal growth, resulting in excessive shedding and an abnormal whip-like growth of the plant as described in the key.

Plants Attacked.—In addition to cotton, croton, evening primrose, goat-weed, sage weed, horsemint, orach, wild sunflower and at least 30 other species of weeds.

Distribution.—General throughout the cotton belt and over much of the United States.

Life History, Appearance, and Habits.—The cotton fleahopper hibernates in the egg stage on croton, sage weed, goatweed, *Atriplex*, and other weeds. In southern Texas it appeared on horsemint early in March, migrated to cotton late in April, and deserted the cotton by the end of July, feeding for the remainder of the season on croton, evening primrose, snap beans, and potatoes. The eggs, which are yellowish white, about $\frac{1}{30}$ inch long by a fourth as wide, are inserted beneath the bark, especially just below the growing tips. In a little over a week they hatch and the greenish nymphs begin sucking the sap from the terminal bud cluster, including young leaves, stems, and squares. The extent of the injury suggests that a toxin may be inserted in the plant as the insect feeds. The nymphs molt five times, and within 10 to 30 days are mature bugs. The adult is about $\frac{1}{8}$ inch long, flattened, elongate ovate in outline, with prominent antennæ, and pale yellowish green in color, with minute black hairs and black specks over the upper surface. The generations are not distinctly separated, as reproduction is continuous throughout the warm season.

Control.—When this insect appears in abundance and there is considerable blasting of the tiny squares, an application of superfine dusting sulfur or flour sulfur at the rate of 10 to 15 pounds per acre is recommended, to be followed at 3- to 7-day intervals by one to four successive dustings. The eradication of weeds and the destruction of cotton stalks during fall and winter are recommended.

[1] *Psallus seriatus* Reuter, Order Hemiptera, Family Miridæ.

References.—Tex. Agr. Exp. Sta. Bull. 339, 1926, and *Bull.* 380, 1928; *S. C. Agr. Exp. Sta. Bull.* 235, 1927; *U. S. Dept. Agr. Dept. Circ.* 361, 1926.

Crayfish or Land Crabs[1]

These pests (Fig. 93), which are not insects but relatives of the food crabs and lobsters, become serious pests of cotton, corn, and some other crops in the lowlands of the lower Mississippi Valley. They make holes down to the water level and in times of wet weather come out and destroy the plants. They can be controlled very effectively by applying ½ ounce of calcium-cyanide dust to each hole during early spring, and closing the holes with soil.

Reference.—U. S. Dept. Agr. Yearbook for 1911, pp. 321, 324, 1912.

[1] Class Crustacea, Order Decapoda, Family Astacidæ.

CHAPTER XV

TOBACCO INSECTS

FIELD KEY FOR THE IDENTIFICATION OF INSECTS INJURING TOBACCO

A. Insects chewing holes in the leaves:

1. Large green caterpillars, up to 4 inches long, with diagonal white bars on the sides and a slender horn at the tip of the body, cling to the vines and rapidly strip off the foliage. Numerous pellets of excrement on the ground. *Hornworms*, page 429.

2. Very small, oval, active, jumping beetles, about 1/16 inch long, dark brown in color, with more or less black across the wing covers, eat tiny "shot holes" in the leaves. *Tobacco flea beetle*, page 424.

3. Large, grayish to brownish hoppers often invade tobacco fields in great numbers from surrounding grass and clover, when these crops are harvested, and rag the leaves severely. *Grasshoppers*, page 327.

B. Insects mining between upper and lower surface of the leaves:

1. Grayish, irregular, blotch mines (later turning brown), especially in the older leaves; grayish-white caterpillars, up to 1/3 or 1/2 inch long, with a pinkish or greenish tinge and brown at each end, may be found in the mines between upper and under leaf surface. *Tobacco leaf miner* or *splitworm*, page 426.

C. Insects boring in the buds or seed pods:

1. Greenish caterpillars with pale longitudinal stripes, up to 1½ inches long, tunnel holes into the leaf buds as the plants begin to top, causing the leaves to be misshapen and pierced by large holes. Later the caterpillars bore into the seed pods. *Tobacco bud worm*, page 426.

2. Green, tan, or blackish caterpillars, nearly 1¾ inches long when full-grown, attack the plant as in *C*, 1, but mostly later in the season. Bodies of the worms sparsely haired, the skin rough and thorny looking under a lens, often heavily striped and with more or less reddish markings. *Corn earworm* or *false bud worm*, page 427.

D. Insects boring into the stem:

1. Yellow to pinkish-white caterpillars, up to 3/5 inch long, live in silken tubes covered with grains of sand, at the surface of the soil. They burrow into the plant below ground and then tunnel upward, causing the plant to wilt and sometimes cutting off the terminal bud. *Tobacco webworm*, page 428.

2. Smooth, tough, yellowish to reddish-brown, six-legged, slender worms, up to 1½ inches long, burrow into the plant at the surface of the soil and hollow out the stalk above and below the entrance hole, causing the plants to wilt. The worms may also eat off the roots. *Wireworms*, or "*pith worms*" (see *N. C. Dept. Agr. Spcl. Bull.*, (Supplement, October, 1909), pp. 46–53).

E. Insects burrowing or uprooting or cutting off the young plants near the surface of the ground:

1. Plump, smooth, greenish, brownish or grayish, more or less spotted or striped caterpillars, up to 2 inches long, eat off the plants at night and hide in the soil during the day. Especially destructive during April, May, and early June. *Cutworms*, page 428.

2. Seed beds in use for more than 1 year become infested with large, white, six-legged grubs, that crawl on their backs over the surface of the ground and burrow

and work up the soil to such an extent that the small plants are covered or uprooted and seriously damaged. *Green June beetle*, page 607.

F. Insects sucking the sap of the plant:

1. Small plants or the leaves or tops of older plants wilt suddenly. Broad, flat, shield-shaped bugs, about ½ inch long and of a buff to greenish color suck at stems, petioles, or veins. *Spined tobacco bug, Euschistus servus* (Say) (*N. C. Dept. Agr. Spcl. Bull.* (Supplement, October, 1909), pp. 58–59).

2. Second-crop and late tobacco leaves yellow and later split and become ragged-looking, due to the feeding of a greenish-black, slender bug, the largest only ⅛ inch long and about one-fourth as broad, with long, slender legs and antennæ. *Tobacco suck fly, Dicyphus minimus* Uhler (see *Fla. Agr. Exp. Sta. Bull.* 48, 1898).

Fig. 275.—Tobacco leaf badly damaged by tobacco flea beetle. (*From Ky. Agr. Exp. Sta. Bull.* 266.)

G. Insects attacking tobacco and tobacco products in storage:

1. Cigars, cigarettes, and package tobaccos, infested with small, white, curved, very hairy grubs and very small, light-brown beetles ($\frac{1}{16}$ inch long) which eat holes through the wrappers or feed within the packages. The beetles have smooth wing covers and antennæ not enlarged at end. *Tobacco beetle*, page 744.

2. Small, white, curved grubs, similar to *G*, 1, but not hairy; and small, rather narrow, oval, reddish-brown beetles, with parallel lines on the wing covers and last 3 segments of the antennæ enlarged, tunnel through tobacco and many other substances. *Drug-store beetle*, p. 745.

Tobacco Flea Beetle[1]

Importance and Type of Injury.—The adult flea beetles chew small rounded holes into or through the leaves, especially from the underside (Fig. 275). They attack the young plants in the seed beds almost as soon as they come up, and often ruin entire beds. After the plants are transplanted, they weaken or kill them in the field. Damage continues until the crop is harvested, the mature leaves often being spotted with holes which greatly lessen the quantity and the quality, especially of cigar-wrapper tobacco. It has been estimated that a flea beetle eats ten times its own weight in a day. The larvæ feed on the roots of tobacco and other plants of the same family, cutting off the small roots and sometimes tunneling into the stalk. As a result of the feeding of the beetles, fungus diseases are encouraged and spread among the tobacco. This is considered the most injurious insect of tobacco, at

[1] *Epitrix parvula* (Fabricius) and *Epitrix cucumeris* Harris, Order Coleoptera, Family Chrysomelidæ.

least in some sections. Morgan estimated the loss in Kentucky and Tennessee in one year (1907) as close to $2,000,000

Plants Attacked.—Tobacco, tomato, potato, eggplant, pepper, nightshade, Jimson weed, ground cherry, and horse nettle are attacked regularly, and many other plants to a less extent.

Distribution.—Probably in all tobacco-growing sections of the United States and Canada.

Life History, Appearance, and Habits.—The brownish, black-clouded, hard-shelled little beetles, only $\frac{1}{16}$ inch long (Fig. 276), hide during the winter in great numbers under leaves, grass, and trash on the ground about tobacco fields, especially along the margins of woods. Here they hibernate or remain more or less active, depending on the temperature. As soon as the plants come up in the seed beds the beetles attack them, increasing in numbers from then until harvest time, when they begin to disappear.

FIG. 276.—Tobacco flea beetle. Adult, about twenty times natural size. (*From U. S. D. A. Farmers' Bull.* 1425.)

The eggs are laid mostly on the surface of the soil under the plant. They hatch in a week, and the delicate, slender, white larvæ burrow into the soil and feed on the fibrous rootlets mostly within a few inches of the surface. They become full grown in a couple of weeks. They are then about $\frac{1}{6}$ inch long by $\frac{1}{60}$ inch thick and dirty white except for the brownish mouth parts. After 4 or 5 days spent as a whitish pupa in the soil, the new adult emerges. There are probably three or four generations a year in the South.

Control Measures.—The ground surrounding the seed bed should be burned over in late winter. Less injury will occur if the seed beds are located as far from good hibernating quarters as possible and at a considerable distance from the new fields. Seed beds should be boarded or planked up on the sides and covered with tobacco cloth having 25 strands to the inch, making the covering beetle-tight. Surrounding the seed bed should be a 2- or 3-foot strip of early-seeded tobacco, protected with poles and cloth and kept dusted with a mixture of 1 pound Paris green in 5 pounds arsenate of lead. If the beetles get into the seed beds the plants should be dusted or sprayed lightly with 1 part Paris green in 5 parts arsenate of lead every 10 days. The poison should be applied while the plants are dry, using about 1 ounce of the mixture to each 100 square feet of seed bed. As the plants are set out, the leaves should be dipped in a mixture of 1 pound powdered arsenate of lead to 10 gallons of water. Or the newly set plants may be dusted with the above mixture of Paris green and arsenate of lead, using 3 or 4 pounds to the acre. After the crop is

harvested, much can be done to check flea beetles by destroying the "suckers" that grow up in the fields.

References.—*N. C. Agr. Exp. Sta. Bull.* 239, 1919; *U. S. Dept. Agr. Farmers' Bulls.* 1352, 1923; and 1425, 1924.

Tobacco Splitworm[1]

This insect is discussed as the potato tuber moth on page 481. When attacking the tobacco, the pinkish-white caterpillars, about $\frac{1}{3}$ inch long, mine between the upper and lower surfaces, especially of older leaves, causing unsightly gray to brown blotches that render the product unfit for cigar wrappers.

Control Measures.—It is advisable to transplant as early as possible and make every effort to mature an early crop. Early leaves that are badly infested should be pruned off and the stubble and sucker growth destroyed. Cleaning up trash about the field and barns will help to prevent injury. Potatoes should not be followed with tobacco or grown near tobacco fields.

Reference.—*U. S. Dept. Agr. Dept. Bull.* 59, 1914.

Tobacco Bud Worm[2]

Importance and Type of Injury.—Tiny, pale-green, striped caterpillars eat into the buds or unfolded leaves of tobacco as the plants begin to top. If the holes are made in the tips of the buds, the leaves that expand from the buds are often ragged and distorted (Fig. 277). If the tiny holes penetrate the unfolded leaves, these leaves will have large unsightly holes when they are fully expanded. The attack on the buds renders the leaves unfit for cigar wrappers and greatly cuts the price. Late in the season the worms also eat into the seed pods of tobacco, destroying the seed.

Plants Attacked.—Tobacco, ground cherry, and other solanaceous plants and also geranium and ageratum.

Distribution.—From Missouri, Ohio, and Connecticut, southward. Most injurious in the Gulf States; rarely in Kentucky and Tennessee.

Life History, Appearance, and Habits.—The bud worm winters in the soil as a mahogany-colored, spindle-shaped pupa, about $\frac{3}{4}$ inch long. The moths emerge in the spring and deposit their eggs singly on the underside of leaves. They are about $1\frac{1}{2}$ inches across the spread wings. The front wings are light green and crossed by four oblique light bands, the inner three of which are edged with black. The tiny larvæ that hatch from the eggs make their way to the buds and crawl down among the unfolded leaves, where they may cause great damage before they are detected. The full-grown larva is $1\frac{1}{2}$ inches long, of a pale-green color and marked with several longitudinal pale stripes. Pupation occurs in the soil, and there are two generations of the insect each season.

Control Measures.—A dose of poison should be placed in each bud before the young larva gets into it. For this purpose a mixture of 1

[1] *Phthorimaea operculella* Zeller, Order Lepidoptera, Family Gelechiidæ.

[2] *Chloridea virescens* Fabricius, Order Lepidoptera, Family Noctuidæ.

pound arsenate of lead in 75 pounds of corn meal is recommended, applying a small quantity directly upon the bud of each plant by hand or by means of a sifter can. As the buds expand, two applications a week from the time the plants are set out until topping of the plants is completed will be needed to give entire protection. If workmen will kill all worms seen while working among the tobacco, much of the damage may be prevented. As soon as the plants are harvested, the remnants should be cut and burned and the soil plowed. Infestation the following year may be reduced if the leftover plants in seed beds are destroyed as soon as

FIG. 277.—Injury to the tobacco plant by the tobacco bud worm. (*From U. S. D. A. Farmers' Bull.* 819.)

planting is finished and the suckers removed from plants and destroyed. The seed beds should be carefully covered as recommended for the tobacco flea beetle.

Reference.—U. S. Dept. Agr. Farmers' Bull. 819, 1917.

Corn Earworm or False Bud Worm[1]

This very destructive pest of corn and cotton (see pages 350 and 416) attacks tobacco in a manner very similar to the tobacco bud worm. It is usually not so destructive to tobacco as the true tobacco bud worm. Very early in the season in the extreme south, and after corn has become mature in most sections, the moths, of which there are several generations, may lay their eggs on tobacco. The caterpillars may be destroyed by the same measures recommended for the tobacco bud worm.

[1] *Heliothus obsoleta* Fabricius, Order Lepidoptera, Family Noctuidæ.

Tobacco Webworm[1]

Importance and Type of Injury.—This small caterpillar, also known as the corn webworm, causes much damage to tobacco in Virginia and adjoining states by cutting into the young plants at the surface of the ground and then boring up or down in the stem. Usually the attack comes after the plants have become established, and it may necessitate one or more replantings.

Plants Attacked.—Tobacco, corn, and certain weeds such as buckhorn, wild carrot, plaintain, asters, and daisies.

Distribution.—Throughout the eastern states, especially destructive in Virginia.

Life History, Appearance, and Habits.—Similar to that given for sod webworms (p. 324).

Control.—No practical control measures are known except the indirect ones described on page 324.

Reference.—*U. S. Dept. Agr. Dept. Bull.* 78, 1914.

Cutworms

Importance and Type of Injury.—Cutworms of several species often cut off newly transplanted tobacco at the surface of the ground in the

Fig. 278.—Tobacco plant ruined by a cutworm with the larva in feeding position. (*From U. S. D. A. Farmers' Bull.* 1494.)

manner discussed under Corn (page 321) and garden crops (page 434) (Fig. 278). Some climbing cutworms attack the leaves of older plants.

Life History, Appearance, and Habits.—The cutworms injurious to tobacco are divided by Crumb (*l.c.*) into two groups. One group, including the variegated cutworm[2] and the black cutworm[3] pass the winter as naked brown pupæ in the soil, transform to moths very early in spring, and produce during the season three or four generations. The species

[1] *Crambus caliginosellus* Clemens, Order Lepidoptera, Family Pyralididæ.

[2] *Lycophotia margaritosa saucia* Hübner, Order Lepidoptera, Family Noctuidæ.

[3] *Agrotis ypsilon* Rottemburg, Order Lepidoptera, Family Noctuidæ.

of this group are destructive throughout the tobacco-growing regions of the United States and Canada. The other group consists of species that lay their eggs chiefly in weedy or grassy fields in late summer or fall. The eggs hatch and the larvæ spend the winter partly grown and feed destructively upon the newly set plants in the spring. These species include the dingy cutworm,[1] the clay-backed cutworm,[2] the dark-sided cutworm[3] and the spotted cutworm.[4] Species of this group are rarely destructive south of Virginia and Tennessee and all but the last named have a single generation a year.

Control Measures.—If cutworms are present, poisoned-bran bait as recommended on page 323 should be applied several days before the tobacco plants are set. To determine whether the bait should be applied, Crumb suggests placing rather large compact bunches of freshly cut clover, dock, or chickweed on well-plowed soil. If cutworms are present in the soil they will collect under such vegetation, and an examination in 2 or 3 days will indicate whether the bait should be applied. Poison-bran bait may be broadcast late in the evening at the rate of 10 to 20 pounds dry weight per acre, or 4 pounds to 100 square yard of seed bed. Or a small handful may be placed about each hill as the plants are set.

References.—*U. S. Dept. Agr. Farmers' Bull.* 1494, 1926; *Fla. Agr. Exp. Sta. Bull.* 48, 1898.

Tobacco Hornworms[5]

The best known of tobacco insects, and among the most injurious, are the large green tobacco worms with white bars on the sides and a slender horn at the end of the body and the parent "tobacco flies," or hawk moths, that lay the eggs of the hornworm. These worms infest the plants all summer long and are such ravenous feeders as to ruin many leaves and, where abundant, defoliate the plants. The life history and descriptions of these pests are given on page 488.

Control.—Where labor is cheap and plentiful, hand picking of these worms is fairly effective and laborers should always be instructed to destroy the worms wherever they are encountered while working among the plants (Fig. 279). Dusting the plants with arsenate of lead 3½ to 5 pounds per acre, applied with a good dust gun when there is no breeze, has been found a very satisfactory control. The first application should be given as soon as the young worms become numerous on the plants and later applications should be given as needed.

Reference.—*U. S. Dept. Agr. Farmers' Bull.* 1356, 1923.

[1] *Feltia subgothica* Haworth (*ducens* Walker.)

[2] *Feltia gladiaria* Morrison.

[3] *Euxoa messoria* Harris.

[4] *Agrotis c-nigrum* (Linné).

[5] *Protoparce sexta* (Johanssen) and *Protoparce quinquemaculata* Haworth, Order Lepidoptera, Family Sphingidæ.

FIG. 279.—Hornworms on tobacco plants, killed by the application of arsenate of lead, Clarksville, Tennessee. (*From U. S. D. A.*)

CHAPTER XVI

INSECTS INJURIOUS TO VEGETABLE GARDENS AND TRUCK CROPS

An abundance of fresh vegetables in the diet is known to be very important to human health. The use of vegetables, now negligible in many families, would be much more extensive if the control of the many insects that discourage the home gardener were better understood. The quality of commercially grown vegetables would be better and the price could be lowered, also, if insects were not permitted to add so much to the expense of production. A very slight amount of feeding upon vegetables such as cucumbers, melons, tomatoes, and lettuce render them unsalable. This makes the insect losses to truck crops high in proportion to the amount of the plant consumed.

A knowledge of the habits, life cycles, and control measures effective against these pests, will enable any grower to reduce very much the extensive damage he suffers from garden insects.

The more important garden insects are discussed under the following groups:

General Reference.—Crosby and Leonard, "Manual of Vegetable-garden Insects," The Macmillan Company, 1918.

A. GENERAL GARDEN PESTS

While many garden insects feed on only one kind of crop or a few closely related ones, there are a number of others that feed on a variety of plants. Some of these are discussed in this section before the pests of special crops are taken up. The following species are general garden

pests. They are also included in the field keys under the crops to which they are most destructive.

Insects that feed on vegetables below ground:

Wireworms, page 432; white grubs, page 433; millipedes, page 434; and garden centipede, p. 699.

Insects that cut the plant off near the surface of the ground:

Cutworms, page 434.

Insects that chew the foliage:

Fall army worm, page 435; flea beetles, page 437; grasshoppers, page 441 and woolly-bear caterpillars, page 441.

Insects that suck sap from the stems and leaves:

Garden aphids, page 442; garden fleahopper, page 445; tarnished plant bug, page 445 and red spider, page 448.

Wireworms[1]

Importance and Type of Injury.—When garden or truck crops are planted on land that has been in sod for several years, the wireworms that were attracted to the grass plants remain in the soil until their life cycle is completed and may damage the vegetables on such plats for from 1 to 5 years. Other species breed and thrive in the intensely cultivated truck-crop areas, and are not bound up with sod conditions in any way. They feed below ground, chewing off small roots and scoring the surface or tunneling through larger roots, tubers, and underground parts of stems. Another serious injury is their habit of feeding on newly planted seeds, which prevents the plants from coming up.

Plants Attacked.—The seeds of corn, beans, peas, the tubers of potatoes, and the roots of turnips, sweet potatoes, carrots, radish, sweet corn, cabbage, cucumber, tomato, onion, watermelon, many other vegetables, and nursery stock suffer from the attacks of these pests.

Distribution.—See Corn Insects, page 304.

Life History, Appearance, and Habits.—These points are discussed under corn insects (p. 304). Some of the species injurious in gardens have a two-year life cycle, while others require at least 6 years. Eggs are not generally laid in gardens or truck patches.

Control Measures.—If a long-standing sod or other field known to be infested is to be planted to vegetables, it should be plowed in midsummer and thoroughly cultivated until cold weather to destroy the pupæ and adults. Some crop not seriously injured by wireworms, such as rape, buckwheat, or clover should be planted in the soil for 2 years following the sod. In the West, certain species of wireworms deposit their eggs by preference in cultivated land. Rotations are not effective for such species.

[1] Several species of the Order Coleoptera, Family Elateridæ.

In small gardens, and in other cases where the value of the crop and the labor costs do not make it prohibitive, wireworms may be trapped by baits made of germinating seeds, such as peas, beans or corn; or of graham or rice flour made into a stiff dough; or of slices of fresh vegetables or bunches of fresh clover or cabbage leaves. These are placed under boards or tiles or buried in the soil 3 or 4 inches deep, at intervals of 4 to 10 feet over the field, the spots being marked with wires or stakes. Wireworms collect about these baits and should be dug out and destroyed once a week after planting the baits. Baits may be drilled into the soil to a depth of 3 inches and the wireworms that collect about them killed by drilling calcium cyanide into the same rows, 10 days to 2 weeks later, to a depth of 5 inches. These treatments should be made about the time early garden vegetables are germinating, on soil plowed the preceding summer or fall and kept free of vegetation. Such fields should not be planted to any crop until the wireworms have been destroyed. Wireworms have been trapped by these means at the rate of from 6,000 to 80,000 per acre. Carbon bisulfide, as a soil fumigant, has been found to be very effective in destroying wireworms, but is too expensive for general use.

References.—*U. S. Dept. Agr. Bur. Entomol. Bull.* 123, 1914; *U. S. Dept. Agr. Farmers' Bulls.* 725 and 733, 1916; *U. S. Dept. Agr. Dept. Bull.* 156, 1915. *Dom. Canada Dept. Agr. Pamphlet* 33, n. s., 1923; *N. Y. (Cornell) Agr. Exp. Sta. Bulls.* 33, 1891 and 107, 1896; *Jour. Econ. Entomol.*, Vol. 17, p. 562, 1924, and Vol. 19, p. 636, 1926.

White Grubs[1]

Like wireworms, white grubs develop from eggs laid chiefly in sod land. When such soil is broken and planted to vegetables, the grubs seriously injure the latter and remain in the same fields 2 to 3 years before they are full-grown. If gardens are allowed to grow up to grass and weeds, the parent May beetles may lay their eggs directly in the garden. All kinds of roots may be eaten, and tubers and fleshy roots like potatoes and beets have the surface scarred and gouged with broad shallow cavities ¼ to ½ inch deep.

Control Measures.—Vegetables should not be planted in soil that has been covered with a grass sod for years, nor in fields where white grubs are abundant. Legumes may be grown in such soil for a year or two until the grubs have disappeared. In general, garden crops should not be planted in soil which was covered with grasses or small grains during a spring in which a heavy flight of May beetles occurred, since such soil is nearly certain to be infested with eggs and grubs for the next 3 years. Clover sod, or fields bearing clean-cultivated row crops during beetle flights, should be given preference for trucking during the years that immediately follow. Gardens that are surrounded by such trees as

[1] *Phyllophaga* spp., Order Coleoptera, Family Scarabæidæ.

poplars, oaks, lindens, willows, ash, maple, and walnut, are usually infested with white grubs every year, because the May beetles are attracted to such trees to feed, and lay their eggs in the soil near-by.

The distribution, life cycle, additional control measures and references for white grubs are given under Corn Insects, page 306.

Millipedes or Thousand-legged Worms[1]

Importance and Type of Injury.—Although not insects, these pests, which are often wrongly called wireworms, injure plants in much the same way as wireworms and white grubs. They eat the roots of various plants, tunnel into the root vegetables and tubers, eat planted seeds, and also devour leaves and bore into fruits that lie in contact with the soil.

Plants Attacked.—Corn, potatoes, parsnips, carrots, beets, turnips, radishes, lettuce, cabbage, cauliflower, beans, peas, tomatoes, muskmelons, cucumbers, squash, and others.

Distribution.—Although these pests are widely distributed, chief complaints of injury in the field have been from New York, Ohio, and neighboring states and the Pacific Coast States.

Fig. 280.—A typical millipede, *Julus impressus*, enlarged. (*From Ill. State Nat. Hist. Sur.*)

Life History, Appearance, and Habits.—The life cycles of millipedes are not well known. They have a simple development. The eggs are laid in the soil, sometimes in masses, and hatch into small worms differing from the full-grown ones in having fewer segments and legs. The adults (Fig. 280) are 1 or 2 inches long and are at once distinguished from insect larvæ by the large number of legs that they possess, two pairs to each apparent body ring, the total number often being more than 100.

Control Measures.—The only control measure known to be effective is to poison or trap the worms with baits similar to those recommended for wireworms. The bait, however, should be placed on the surface of the soil in balls or small piles. Care must be taken to keep poultry away from the piles of poisoned bait.

Cutworms[2]

Importance and Type of Injury.—Recently set or young seedling plants are often cut off during the night at the surface of the soil (Fig. 278) and left lying to wilt on the ground near-by. Plump, soft-skinned, greasy-looking caterpillars, varying in length up to 1½ inches or more, which generally roll the body tightly when disturbed, and "play 'possum," are found in shallow holes in the soil about the base of the plants. Some species climb up the plants and eat at the leaves or chew their way into fruits, such as tomatoes, while still others feed entirely below ground. Several species, when they become abundant, crawl from the fields where they developed, in great numbers like marching armies, and may invade gardens and rapidly devour all kinds of garden crops.

[1] *Julus impressus*, *Julus hortensis* Wood, *Julus hesperus* Cham., Class Diplopoda.
[2] Various species of Order Lepidoptera, Family Noctuidæ.

Plants Attacked.—Nearly all garden vegetables, as well as flowers, field crops, and fruit trees are attacked by cutworms of one kind or another.

The distribution and life history of cutworms are discussed under Corn Insects, page 321, and Tobacco Insects page 428.

Control.—Sod or weedy land intended for vegetables should be plowed in late summer and kept fallow until late in the fall, since it is during this period that the cutworm moths lay their eggs, chiefly on rough, grassy, or weedy land. Some species of cutworms, however, deposit their eggs on fence posts and the stems of large weeds along fences and ditches. In small gardens certain measures are practicable that cannot be used on field crops. The worms may be concentrated by laying small boards about the garden or they may be dug out and destroyed by hand. Some gardeners place cylinders of tin (such as tin cans with bottoms cut out) partly sunk in the soil about choice plants when they are transplanted, to keep the cutworms away. The poison baits recommended under corn insects are effective for many species.

Fall Army Worm[1]

Importance and Type of Injury.—Besides the army cutworms and the true army worm (see p. 318), this insect, which is a member of the same family, often develops the marching habit, the caterpillars crawling in great droves, which may be very injurious to field and vegetable crops. They eat the foliage and tender stems of many plants, often taking everything clean as they go, and then disappear suddenly. They are especially bad in seasons following a cold wet spring, in the South.

Plants Attacked.—Plants of the grass family are probably the preferred food, and the insect is often called the "grass worm;" but it attacks also potato, sweet potato, turnip, spinach, tomato, cabbage, and cucumber among the garden crops, and cotton, tobacco, all grain crops, clover, alfalfa, and cowpeas.

Distribution.—Over the United States, west to New Mexico and Colorado and north to Montana, Minnesota, Michigan, and New Hampshire; more destructive over the Southern States and southward into Mexico, Central America, and the West Indies.

Life History, Appearance, and Habits.—This tropical insect is apparently unable to live through the winter in any section where the ground freezes hard. In southern Florida and Texas, several stages may be present and more or less active during the winter months. In the spring, as they increase in numbers, swarms of moths are produced that fly northward, sometimes covering hundreds of miles before they alight to lay their eggs, usually on the leaves of grass plants. The small larvæ feed down near the ground, chiefly at night, and are not generally

[1] *Laphygma frugiperda* Smith and Abbott, Order Lepidoptera, Family Noctuidæ.

noticed until they have reached a length of 1 or 1½ inches, by which time, if abundant, they are consuming so much grass or grain that they create alarm. The full-grown larvæ (Fig. 281) vary in color from light tan or green to nearly black. They have three yellowish-white hair lines down the back from head to tail; on the sides next to the yellow

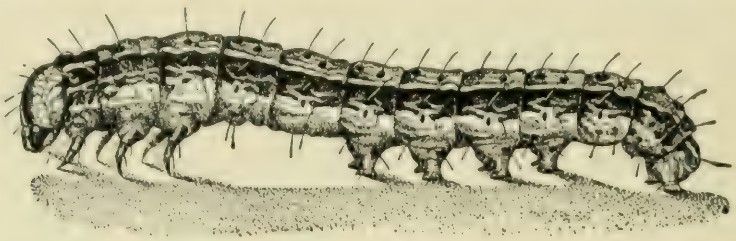


FIG. 281.—Larva of the fall army worm, side view, about twice natural size. (*From U. S. D. A. Tech. Bull.* 34.)

lines is a wider dark stripe and next to it an equally wide, somewhat wavy yellow stripe, splotched with red. These worms are very similar to the true army worm in appearance, but can be distinguished by the more prominent white inverted Y on the front of the head, and by the more prominent black tubercles from which the fine scattered hairs on

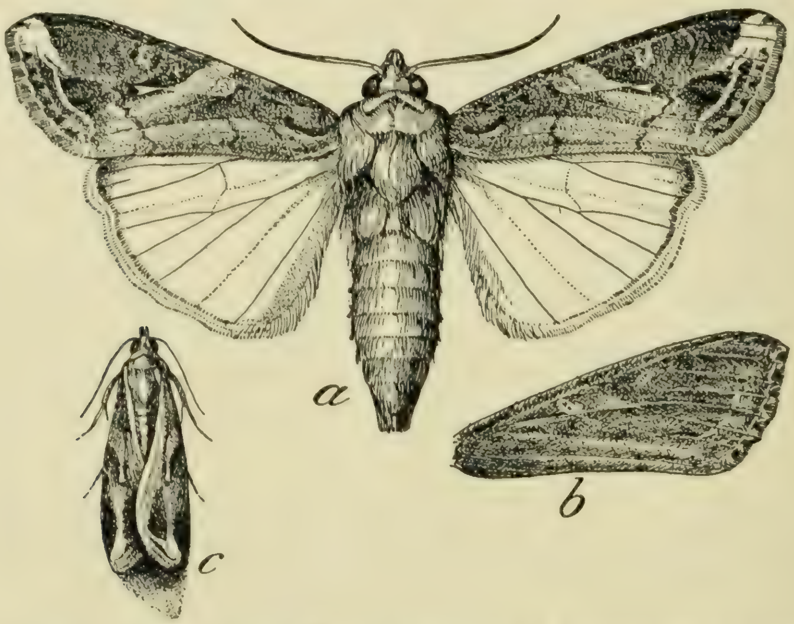


FIG. 282.—Adult of the fall army worm; *a*, male; *b*, right front wing of female. About twice natural size. *c*, moth in resting position about natural size. (*From U. S. D. A. Tech. Bull.* 34.)

the body arise. The corresponding hairs on the true army worm are much shorter and the tubercles smaller. The fall army worm can be distinguished from the army worm, also, by the fact that it feeds on cotton, tobacco, legumes, and many vegetables as well as grasses, while the army worm feeds chiefly on grains and grasses and attacks other plants only when driven by hunger.

When abundant, the caterpillars eat all the food at hand and then start to crawl in great armies into adjoining fields. Gardens may be invaded and consumed in a few nights. Suddenly when full-grown all the caterpillars disappear almost as if by magic, having dug into the ground 1 to 2 inches to pupate. Within 2 weeks a new swarm of moths emerges from the ground, which generally flies far to the north before laying eggs, and so the entire country may be invaded during the summer. The adult moth (Fig. 282) is similar to many cutworm moths, about 1½ inches across the wings, the hind wings grayish white and the front pair dark gray, mottled with lighter and darker splotches and having a noticeable whitish spot near the extreme tip. They are active mainly at night and not much noticed. Only one generation of larvæ is usually abundant in any one community in the North, but in the South there may be five or six generations in the same locality in one year.

Control Measures.—In favorable seasons a number of parasitic enemies keep the fall army worm caterpillars down to moderate numbers. As is generally the case, however, cold, wet springs check the parasites more than they do the insects that they feed upon. In such seasons, especially, watch should be kept of grassy fields for the appearance of the young worms. If they appear, the infested spots should be sprayed with arsenate of lead, 1½ pounds to 50 gallons of water, or treated with poisoned-bran bait as described on page 319. After the worms have begun to march, they can be checked by plowing a deep furrow with dusty sides and killing the worms that accumulate in the furrow by dragging a log back and forth through it. After the worms have disappeared, fields in which they have been feeding should be disked or otherwise lightly cultivated, if practicable, to break up the pupæ and throw them out on the surface, where natural enemies and weather conditions will destroy many of them. Keeping fields of cotton and corn free from grass will do much to prevent injury by this insect, since the infestations almost always start among grasses.

References.—*U. S. Dept. Agr. Farmers' Bull.* 752, 1916; *U. S. Dept. Agr. Tech. Bull.* 34, 1928.

FLEA BEETLES[1]

Importance and Type of Injury.—The name *flea beetle* is applied to a variety of small beetles which have the hind legs enlarged and jump vigorously when disturbed. Since they are small, and also rather active, they do not take much food in one spot and their injury consists of very small, rounded or irregular holes eaten through or into the leaf, so that leaves look as though they had been peppered with fine shot (Fig. 61, *I*). When flea beetles are abundant the foliage of garden plants may be so badly eaten that it can no longer function and the plant dies. These

[1] Order Coleoptera, Family Chrysomelidæ.

small holes give an opportunity for the entrance of destructive plant diseases; and the beetles may carry the disease organisms from one plant to another and spread them as they feed. The potato flea beetle is a means of spreading early potato blight in this way. Besides the injury by the adults, the larvæ of some flea beetles commonly feed on the roots of the same plants, riddling them with tunnels or eating off small rootlets. The larvæ of other kinds feed, along with the adults, on the foliage, or mine in the leaves or tunnel in the stems.

Plants Attacked.—Some flea beetles are rather general feeders, but perhaps the majority attack only one plant or the closely related crops of a single plant family. Among the most destructive garden species are the potato flea beetle,[1] eggplant flea beetle,[2] spinach flea beetle,[3] horse-radish flea beetle,[4] sinuate-striped flea beetle,[5] striped cabbage flea beetle,[6] and sweet-potato flea beetle.[7]

Fig. 283.—The potato flea beetle, *Epitrix cucumeris* Harris, adult; line shows natural size. (*From Chittenden, U. S. D. A.*)

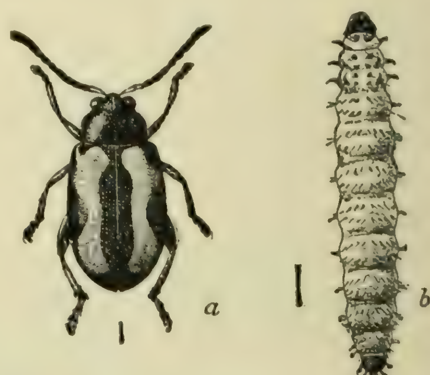


Fig. 284.—The striped cabbage flea beetle, *Phyllotreta vittata* Fab., *a*, adult, *b*, larva. Lines show natural size. (*From Riley, U. S. D. A.*)

Life History, Appearance, and Habits.—The life history varies greatly with the different species. Usually the winter is passed in the adult stage, the beetles hibernating under leaves, grass, or trash about the margins of fields, along ditch banks, fence rows, margins of woods, and similar protected places. The potato flea beetle[1] (Fig. 283) and eggplant flea beetle[2] are about 1/16 inch long and nearly uniform black in color. The equally small, tobacco flea beetle[8] is yellowish brown with a dark cloud across the wings, and the sweet-potato flea beetle[7] (Fig. 316) is of about the same size but with a bronzy reflection. The striped cabbage flea beetle[6] (Fig. 284) and the sinuate-striped flea beetle[5] are about

[1] *Epitrix cucumeris* Harris

[2] *Epitrix fuscula* Crotch.

[3] *Disonycha xanthomelæna* Dalman.

[4] *Phyllotreta armoraciæ* (Koch).

[5] *Phyllotreta zimmermanni* (Crotch).

[6] *Phyllotreta vittata* Fabricius.

[7] *Chætocnema confinis* Crotch.

[8] *Epitrix parvula* Fabricius.

1/12 inch long, with a curious, crooked, yellowish stripe on each wing cover. The pale-striped[1] and horse-radish flea beetles[2] are 1/8 inch long, with a broader, nearly straight, yellowish stripe on each wing cover; the smartweed flea beetle,[3] of the same size, is bluish black, without stripes, and very straight-sided. Among the largest of our common species is the spinach flea beetle[4] (Fig. 287), which is fully 1/5 inch long, with greenish-black wing covers, a yellow prothorax and dark head. Nearly all of these species are elongate oval in outline, with narrowed prothorax and narrower head. The antennæ are one-half to two-thirds as long as the body, and the hind femora are distinctly thickened, enabling the beetles to jump away quickly when they are disturbed. Many of the species

Fig. 285.—Eggs of the spinach flea beetle, *Disonycha xanthomelæna* Dalman, about ten times natural size. *(From Ill. State Nat. Hist. Sur.)*

Fig. 286.—Larva of spinach flea beetle, dorsal view, about ten times natural size. *(From Ill. State Nat. Hist. Sur.)*

Fig. 287.—Adult of spinach flea beetle, about ten times natural size. *(From Ill. State Nat. Hist. Sur.)*

emerge from hibernation and feed on weeds and the foliage of trees until the garden plants are available, when they migrate to them.

[1] *Systena tæniata* Say.

[2] *Phyllotreta armoraciæ* (Koch.)

[3] *Systena hudsonias* Forster.

[4] *Disonycha xanthomelæna* Dalman.

They are frequently serious pests in seed beds and on newly transplanted vegetables. The eggs, which are so small as never to be seen by the grower, are scattered in the soil about the plants, by the potato flea beetle and the tobacco flea beetle, and laid in clusters of a dozen or two by the spinach flea beetle (Fig. 285). The striped cabbage flea beetle deposits her eggs in tiny cavities gnawed in the stem of the plant, the horse-radish flea beetle deposits them in clusters on the leaf petioles and the sinuate-striped flea beetle lays her eggs singly on the leaves of cabbage, turnip and radish. The larvæ of flea beetles are mostly whitish, slender, delicate, cylindrical worms from $\frac{1}{8}$ to $\frac{1}{3}$ inch long when full-grown, with tiny legs and brownish heads. They feed on the roots, underground stems, or tubers of vegetables or of weeds. The larvæ of the sinuate-striped species, however, mines in the leaves, the horse-radish flea beetle burrows in the leaf petiole and the spinach flea beetle feeds exposed on the underside of the leaves. The last-named species (Fig. 286) is a short, leaden gray, wrinkled grub about $\frac{1}{4}$ inch long in the full-grown larval stage. Pupation usually occurs in the soil. There are generally one or two generations a year.

Control Measures—Flea beetles are hard to control, since arsenicals are apparently distasteful to them and they do not readily eat enough sprayed foliage to be killed by the poison. Best results have generally been secured by applying Bordeaux mixture as a repellent. (See p. 260.)

To control flea beetles, it is necessary to apply poisoned Bordeaux very thoroughly to the plants at 10-day intervals, since these insects detect any unsprayed portions of the foliage and feed upon them. Plants such as tomatoes and eggplant may be dipped in poisoned Bordeaux when they are transplanted. Recently arsenate of lead, alone, has been recommended for the eggplant flea beetle and a nicotine dust 3 per cent in hydrated lime for the cabbage flea beetle.

Seed beds may be covered with strips of gauze or tobacco cloth, 25 strands to the inch, to exclude these pests from delicate young plants. Sticky shields or specially made boxes having the inner walls covered with tree tanglefoot may be passed over infested plants and catch thousands of the beetles as they jump off the disturbed plants.

Keeping down weeds in and around the garden is often the most important method of holding these pests in check, since the adults often feed on weeds in early spring and late in fall, and the larvæ may develop in great numbers on the roots of certain weeds.

References.—Crosby and Leonard, "Manual of Vegetable-garden Insects," 1918; *U. S. Dept. Agr. Dept. Bulls.* 535, 1917 and 902, 1920; *N. Y. (Geneva) Agr. Exp. Sta. Bull.* 442, 1917; *N. Y. (Cornell) Agr. Exp. Sta. Mem.* 55, 1922; *Dom. Canada, Dept. Agr. Entomol. Circ.* 2, 1913 and *Pamphlet* 80, n. s., 1927.

Grasshoppers[1]

In years when grasshoppers are abundant, they may become serious on garden crops, especially where the gardens are surrounded by fields of clover or by waste lands in which they have not been controlled. The ravenous hoppers strip the leaves and eat the tender stems from almost all kinds of vegetable crops. These insects are more fully treated under Corn Insects, page 327.

To protect gardens from the attack of grasshoppers it will be necessary to treat the garden and surrounding fields or waste lands with a poisoned bait as recommended on page 331, or to keep the plants covered with poison spray or dust.

Woolly-bear,[2] Yellow-bear,[3] and Salt-marsh Caterpillars[4]

Importance and Type of Injury.—Very hairy or woolly, yellowish and brown caterpillars (Fig. 288), ranging up to 2 inches in length, riddle the foliage of many

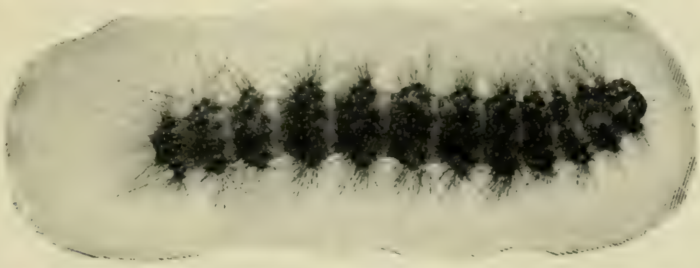


Fig. 288.—The salt-marsh caterpillar, *Estigmene acræa* Drury, larva, natural size. (*From Ill. State Nat. Hist. Sur.*)

garden crops in summer and autumn. The smaller worms are usually found feeding together on the underside of leaves. The larger ones feed exposed, and when full-grown are often seen in the autumn scurrying over the surface of the ground, apparently in great haste to get somewhere.

Plants Attacked.—One or more of these species attack practically all of the garden crops.

Distribution.—General throughout the United States.

Fig. 289.—The salt-marsh caterpillar, male moth, natural size. (*From Ill. State Nat. Hist. Sur.*)

Life History, Appearance, and Habits.—The woolly-bear winters in the larval stage in some protected place and feeds briefly in the spring before changing to a pupa. The other two species hibernate in the pupal stage inside thin silken cocoons heavily covered with interwoven hairs from the body of the caterpillar. The adults are snow-white, or yellowish-winged moths, from $1\frac{1}{2}$ to 2 inches across the wings, with yellowish, black-spotted abdomens. The yellow bear adult is nearly pure white

[1] Many species of Order Orthoptera, Family Locustidæ.

[2] *Isia isabella* Smith and Abbott, Order Lepidoptera, Family Arctiidæ.

[3] *Diacrisia virginica* Fabricius.

[4] *Estigmene acræa* Drury.

except for the abdomen, each wing having a few small black spots. The salt-marsh caterpillar adult has the wings peppered with a number of small black spots, white above and yellow below, in the female, and in the male (Fig. 289) the hind wings yellow both above and below. The adult of the woolly-bear is entirely yellowish and with a few black spots on the wings. The adults appear in spring and lay their spherical eggs in patches on the leaves. The larvæ attain full size in a month or two. The woolly-bear larva is black at each end, with a median band of brown of variable extent, and, as pointed out by Comstock, has an evenly clipped appearance. The other two species have hairs of different lengths, yellowish, tawny, or grayish in color, and not so dense as completely to hide the skin. There are generally two generations a year in the North.

Control Measures.—These caterpillars are readily killed by a thorough application of arsenate of lead (2 pounds to 50 gallons) or other stomach poison. The larger ones may be killed by hand.

Plant Lice or Aphids[1]

Importance and Type of Injury.—Nearly every garden crop and almost all other kinds of growing plants are attacked by small, soft-bodied insects, known as aphids or plant lice, which are about as big as pinheads on the average, and most often green in color, although some are brown, yellowish, pinkish, or black (Fig. 290). They all feed by thrusting sharp hollow stylets, from their beaks, in among the cells of the plant and sucking out the sap. This causes the blighting of buds, dimpling of fruits, curling of leaves or appearance of discolored spots on the foliage. As the aphids become more abundant, the plants gradually wilt from loss of sap and possibly by being poisoned by the saliva of the aphids; the leaves may become yellowish or brown, and the plant usually dies.

The presence of aphids makes vegetables unattractive and detracts from their flavor and market value, and when they occur in small numbers may occasion much work to remove them in preparing the vegetables for use. They excrete a honeydew from their intestines that gums up the plants and often serves as a medium on which a fungus may grow that further spoils vegetables. Recently it has been shown that aphids are important natural agencies in spreading certain plant diseases, such as mosaics and blights; and this phase of damage may exceed in seriousness their direct injury by feeding.

Plants Attacked.—All the vegetables of the cabbage family, cucumbers, melons, beans, peas, potatoes, tomatoes, lettuce, turnips, spinach, and other garden crops have serious aphid pests.

Distribution.—As a group, world-wide; and many species are nearly cosmopolitan.

Life History, Appearance, and Habits.—Aphids (Fig. 290) typically winter as fertilized eggs on some perennial plant; some winter on the dead remnants of annual vegetables; while the overwintering condition of some species is not known. The eggs are small, ovate, blackish objects, glued

[1] Many species of the Order Homoptera, Family Aphididæ.

FIG. 290.—Garden aphids. *(Reprinted from "Insect Pests of Farm, Garden, and Orchard" by Sanderson and Peairs, published by John Wiley & Sons, Inc., after U. S. D. A.)*

on their sides generally to the stems of plants or in crevices about the buds. (Fig. 353). When the weather becomes warm enough, small nymphs hatch from the eggs, which grow quickly to full size but never get wings. Since each of these is the start for a great colony of aphids that may be produced during the season, they are called *stem-mothers*. They are all females which have the remarkable ability to reproduce young like themselves, without mating. These young are born ovoviviparously, that is, already hatched from the egg; and differ from their stem-mothers, in having only one parent and in not passing through an exposed egg stage. They are like the stem-mothers in being wingless and in producing young ovoviviparously, beginning when they themselves are only a week or so old and producing from a dozen to 50 or 100 active nymphs within the next week or two. In this way a succession of generations is produced, the young clustering about their mothers until patches on the plant may be crowded with them. At some time during this period, either all or a part of certain generations of these females may develop wings. These may fly to other plants of the same kind, or in some species they habitually fly to a different kind of plant (usually an annual), known as the *summer host*. Such winged ones are called *spring migrants*. They settle down on the new host plant and start a succession of generations there; all produced, as before, from unfertilized eggs that hatch in the body of the mother.

As shortening days forecast the end of the season, and before the summer-host plant dies, a generation is usually produced that is all winged, but is often of two kinds. Some of them are winged males, the first appearance of males in the aphid colonies being at the approach of cold weather. The others are winged females which are called *fall migrants* and which may serve to return the species to the kind of perennial plant from which their distant ancestors flew away in the spring. These fall migrants give birth to nymphs in the normal manner, but the nymphs, when grown, are wingless true females that cannot reproduce unless they mate with the males which are of the preceding generation. After mating, the true female lays from one to four or more large fertilized eggs in a sheltered place about the plant, and dies; or, sometimes, simply dries up about the single egg she is capable of maturing. From these eggs arise the stem-mothers of the next spring, which differ from all the hosts of other aphids produced during the year in having both male and female parents. In some species, the males and true females have no mouth parts.

This is a kind of standard life cycle. Variations from it will be noted in the discussion of particular species, but the essential features of this life cycle should be fixed in mind because the details are not repeated for the aphids discussed under particular crops.

Control Measures.—Nicotine is the standard remedy for aphids. It may be applied as a spray or as a dust. For certain low-growing, dense

rops such as melons, turnips, and the like, dusting is superior because the lust will circulate among the plants and even penetrate into curled leaves nd reach the aphids in positions where a spray could not be driven. Directions for making nicotine dusts are given on page 241. Dusts for garden aphids should contain from 2 to 4 per cent nicotine.

A spray made of ¾ pound 40 per cent nicotine sulphate, 3 pounds aundry or potash fish-oil soap, and 50 gallons of water, is effective against all aphids wet by the spray. For small quantities, use 2 teaspoonfuls

Fig. 291.—The garden fleahopper, *Halticus citri* Ashmead. *a*, short-winged female; *b*, long-winged female; *c*, male; *d*, side view of head showing piercing-sucking mouthparts. Lines indicate natural size. (*From Chittenden, U. S. D. A.*)

of nicotine sulphate to each gallon of water, in which 1 cubic inch of soap has been dissolved as a spreader. Some derris preparations are as good as nicotine sulphate. Strong soap solutions (1 pound to 3 or 4 gallons of water) are effective against certain species of aphids. Certain types of oil emulsions, at a strength of 2 to 5 per cent oil, are very effective, but others will seriously burn garden plants.

Reference.—"The Life-cycle of Aphids," In *Annals Entomol. Soc. Am.*, Vol. 13, pp. 156–162, 1920.

Garden Fleahopper[1]

Importance and Type of Injury.—These small bugs look somewhat like black aphids, and they suck the sap from leaves and stems in a manner like aphids. Small

[1] *Halticus citri* Ashmead, Order Hemiptera, Family Miridæ.

pale spots often appear on the leaves where the fleahoppers have sucked out the sap, and badly infested leaves are killed. The insect occurs sporadically.

Plants Attacked.—Bean, beet, cabbage, celery, corn, cowpea, cucumber, eggplant, lettuce, pea, pepper, potato, pumpkin, squash, sweet potato, tomato, various legumes, ornamentals, and many weeds.

Distribution.—General throughout the United States, except in the western part.

Life History, Appearance, and Habits.—The insect winters in the adult stage. In the spring, the females insert their eggs in the leaves or stems of the plants on which they feed, the eggs being laid in punctures made by the mouth parts. The greenish nymphs of various sizes appear on the underside of the leaves in early spring and grow rapidly to blackish adults. The females (Fig. 291) are of two kinds: a long-winged form (*b*), which is $\frac{1}{12}$ inch long by about one-third as wide, nearly straight-sided, and with the overlapping tips of the wings transparent; and a short-winged form (*a*), about $\frac{1}{10}$ inch long, oval-bodied, and more than half as wide as long. The latter form lacks the transparent tips of the wings, and this, together with the jumping habit of the species, gives it a strong resemblance to a flea beetle. The legs are long and the antennæ are longer than the body and very slender. Five generations have been recorded in South Carolina.

Control Measures.—A spray of 40 per cent nicotine sulphate, 1 to 700, with soap, or a 3 per cent nicotine dust, applied so as to hit all of the insects, is an effective control for this pest. Destruction of the weeds on which the insect lives will do much to keep it from reaching serious numbers.

Reference.—U. S. Dept. Agr. Dept. Bull. 964, 1921.

Tarnished Plant Bug[1]

Importance and Type of Injury.—This small, brownish, flattened bug is provided with piercing-sucking mouth parts with which it takes the sap of a great variety of plants. As it feeds it appears to introduce some poisonous substance into the plant. Its feeding causes various sorts of injuries; the leaves may become deformed, as in beets and chard; the stems or leaf petioles scarred and discolored, as in the "black joint" of celery; or the buds and developing fruit dwarfed and pitted, as in the case of beans, strawberries, and peaches (see Fig. 410.)

Plants Attacked.—Beet, chard, celery, bean, potato, cabbage, cauliflower, turnip, salsify, cucumber, cotton, many flowering plants, and most deciduous and small fruits—more than 50 economic plants, besides many weeds and grasses.

Distribution.—Throughout the United States, and in many other parts of the world.

Life History, Appearance, and Habits.—The adult bugs, and probably also the nymphs, hibernate under leaf mold, stones, bark of trees, among the leaves of such plants as clover, alfalfa, and mullein, and in many other protected places. They are about $\frac{1}{4}$ inch long by less than half as broad, flattened, oval in outline, with the small head projecting in front, and of a general brown color much mottled with small, irregular splotches of white,

[1] *Lygus pratensis* Linné, Order Hemiptera, Family Miridæ.

yellow, reddish-brown, and black. Along the side of the body at the posterior third is a clear yellow triangle (the cuneus) tipped with a small, round, intensely black dot (Fig. 292). They become active very early in spring, when they attack the buds of fruit trees, causing serious injury to the terminal shoots and fruits (see p. 611). They do not appear to lay their eggs on these plants to any great extent, but migrate to various herbaceous weeds, vegetables, and flowers, where the eggs are either inserted full length into the stems, petioles, or midribs of leaves or into buds, or are tucked in among the florets of the flower head. The egg is elongate, slightly curved, and the outer end is cut square off, the lid which covers this end being usually flush with the stem. After about 10 days, a small yellowish-green nymph $\frac{1}{25}$ inch long, oval in outline and provided with long legs, antennæ, and piercing-sucking mouth parts,

Fig. 292.—Adult of the tarnished plant bug, *Lygus pratensis* Linné, about three times natural size. (*From Ill. State Nat. Hist. Sur.*)

Fig. 293.—Tarnished plant bug, nymph, last instar, about three times natural size. (*From Ill. State Nat. Hist. Sur.*)

emerges from the egg and begins feeding on the sap. It grows rapidly, molting five times, the larger nymphs gradually taking on the appearance of the adult and being marked with four rounded black dots on the thorax and one on the base of the abdomen (Fig. 293). The life cycle is completed in 3 or 4 weeks, so that probably three to five generations occur each season. By late summer they occur everywhere in profusion, but because of their obscure and protective coloration and shy and hiding habits are not much noticed.

Control Measures.—No effective control for this pest is known. Cleaning up of weeds and destruction of favorable hibernating places may help to keep their numbers down. Haseman recommends the use of sticky shields. On a few valuable plants they may be controlled by dusting with a 5 per cent nicotine dust, applied under a tight canvas, to confine the fumes. On potatoes, Bordeaux mixture has been found to be somewhat repellent.

References.—*Mo., Agr. Exp. Sta. Research Bull.* 29, 1918; *N. Y. (Cornell) Agr. Exp. Sta. Bull.* 346, 1914.

Red Spider[1]

Importance and Type of Injury.—In periods of dry hot weather, the leaves of beans and other plants become blotched with pale yellow and reddish-brown, in spots ranging from small specks to large areas, on both upper and under surfaces, and the leaves have a pale, sickly appearance and gradually die and drop. The under surfaces of such leaves look as though they had been very lightly dusted with fine white powder. When examined under a lens, the fine white specks are seen to consist of empty wrinkled skins and minute spherical eggs and to be suspended on almost invisible strands of silk. Upon this silk, and beneath it on the surface of the leaf, are resting or running about numerous minute, whitish, greenish or reddish, eight-legged mites of several sizes (Fig. 294). These mites live upon the sap of the plant, which is drawn by piercing the leaf with two sharp slender lances attached to the mouth. Besides the loss of sap it seems possible that the leaves are poisoned by the feeding of the mites.

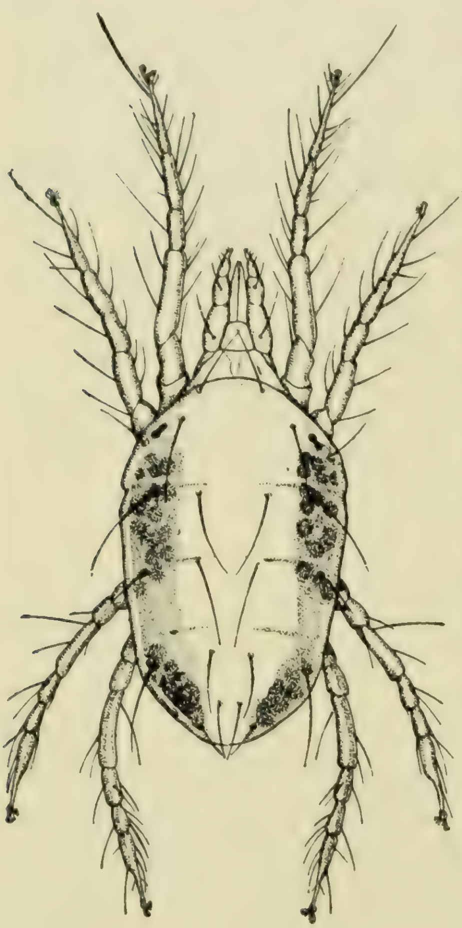


Fig. 294.—The common red spider, *Tetranychus telarius* Linné, adult female, highly magnified. (*From U. S. D. A. Farmers' Bull.* 831.)

Plants Attacked.—The vegetable crops most seriously injured by the red spider are beans, corn, tomato, eggplant and onion. Additional food plants and the life history are given in the discussion of this mite as a greenhouse pest, page 712.

Distribution.—World-wide.

Control Measures.—According to MacGregor, this pest may be kept in subjection by the winter destruction of such weeds as pokeweed, Jerusalem oak, Jimson weed, wild blackberry, and wild geranium, about the garden, and by the destruction or spraying of violets, berry bushes, and other host plants, wherever they retain green foliage over the winter. Once a garden is infested, a very thorough spraying, so as to cover the underside of all infested leaves with one of the following sprays, will check them. The application should be repeated a week later to destroy such mites as were in the egg stage at the first spraying.

[1] *Tetranychus telarius* Linné, Class Arachnida, Order Acarina, Family Tetranychidæ.

All mites covered will be killed by a spray of potassium sulphide 1 ounce in 2 gallons of water; or by lime-sulphur 1 part commercial 33° Baumé strength, to 40 parts of water. Certain types of oil emulsions, at a strength of 2 per cent oil, have been found effective, as has, also, superfine dusting sulfur.

References.—*U. S. Dept. Agr. Dept. Bull.* 416, 1917; *Ore. Agr. Exp. Sta. Bull.* 121, 1914.

B. INSECTS INJURIOUS TO PEAS AND BEANS

FIELD KEY FOR THE DETERMINATION OF INSECTS INJURING PEAS AND BEANS

A. Insects attacking the seeds, either in storage or within the pods in the field:

1. Peas within the pod partly eaten, showing irregular superficial cavities, web-covered, and surrounded by granular pellets of excrement, among which is a white caterpillar, up to ½ inch long. *Pea moth*, page 450.

2. Seeds of peas, beans, vetch, and locust trees attacked in the green pods by a caterpillar up to 1 inch in length, and varying from white or greenish to reddish in color. *Legume-pod moth* (*Etiella zinckenella* Treit) (see *U. S. Dept. Agr. Bur. Entomol. Bull.* 95, Part VI, p. 82, 1912).

3. Interior of peas and beans in the field and in storage devoured by short, white, footless grubs and chunky, brownish beetles, from ⅛ to ⅕ inch long. *Pea weevil* and *bean weevils* (see further key on page. 734).

B. Insects eating holes in the leaves:

1. A coppery-brown, oval beetle, ¼ inch long, with eight small black spots on each wing cover, eats irregular holes from underside of leaves; or oval, yellow, very spiny larvæ up to ⅓ inch long eat rectangular holes from under side of leaves, the holes separated by slender parallel strips of leaf that are untouched. Both the adult and the larva leave the transparent upper epidermis uneaten. *Mexican bean beetle*, page 451.

2. Reddish to yellowish beetles, ⅙ inch long, usually with three black spots in a row along inner edge of each wing cover and costal margin also edged with black, eat round holes through the leaf. *Bean leaf beetle*, page 453.

3. A greenish or yellowish beetle ¼ inch long, with six black spots on each wing cover, eats irregular holes in the leaves. *Spotted cucumber beetle*, page 454.

4. A uniformly tan-colored beetle, about ⅙ inch long, the wing covers with regular rows of small punctures, eats irregular holes in the leaves. *Grape colaspis*, page 313.

5. Irregular holes, usually extending from the margin of leaf inward, eaten by robust, brown or grayish, elongate, wedge-shaped insects up to 1½ inches long, with short or long wings and the third pair of legs very long. Jump vigorously when disturbed. *Grasshoppers*, page 327.

6. Very hairy, yellowish, brown or reddish-brown and black-banded caterpillars eat the foliage. *Woolly bears*, page 441.

7. Very large holes or entire leaves eaten at night by fleshy, grayish or brownish, slimy, wormlike creatures, without legs or segmentation, up to 3 inches long. Hide under trash about base of plants during the day. *Garden slugs* (not insects), p. 728.

C. Insects sucking sap from leaves and stems:

1. Small, greenish, long-legged, winged or wingless aphids up to ⅙ inch long with two slender tubes projecting from body near tip of abdomen, cluster on underside of leaves and along stems of peas and suck sap, causing plants to wither. *Pea aphid*, page 455.

2. Similar to the above on terminal growth of beans, but not over half as large, and nearly black in color. Plants often become covered with a black "soot." *Bean aphid*, Aphis rumicis Linné (See *Annals Applied Biol.* Vol. 8, p. 51; 9, p. 135; 10, p. 35).

3. Similar to *C*, 2, but 1/10 inch long and lacking the tubes on abdomen. Jumps readily when disturbed. Wings thick, at least at base. *Garden fleahopper*, page 445.

4. The foliage of beans is dwarfed and rosettes form, or small triangular brown areas appear at tips of leaves, gradually spreading around entire margin, the middle of the leaf browning last of all. One or more winged or wingless, elongate, wedge-shaped, green bugs up to 1/8 inch long by one-fourth as broad, found on lower side of leaves; run or jump quickly when disturbed. *Apple leafhopper*, page 475.

5. Leaves become blotched with red and yellow, and die. Underside of leaf with inconspicuous white webs among which are many microscopic, eight-legged, reddish or greenish mites and their round pearly eggs. *Red spider*, page 448.

D. Insects cut off plants near surface of ground or feed on underground parts:

1. Plants chewed just below surface of soil or roots eaten off by a slender white worm up to 1/3 inch long, with six short legs and dark head and tip of body. Plants wilt and die. Larvæ of *bean leaf beetle*, page 453.

2. Plants chewed off near the surface of the ground and sometimes dragged to burrows in the soil. Dull green, brown, gray, or black, cylindrical, greasy-looking worms, variously striped or spotted, with distinct head, six short slender legs on the thorax, and five pairs of prolegs, up to 1½ or 2 inches long, are found in the soil about plants during the daytime. *Cutworms*, page 434.

3. Elongate, brownish, cylindrical or somewhat flattened worms, with many legs, up to 1 or 1½ inches long, eat the roots and the foliage that rests on the soil. Distinguished from wireworms by having one or two pairs of legs on each body segment. *Millipedes* or *thousand-legged worms* (not insects), page 434.

E. Plants fail to come up from seed:

1. The germ of the softened kernel has been eaten out by one or more yellowish-white, footless maggots, pointed at the head end; ¼ inch long. *Seed-corn maggot*, page 300.

2. Seeds have been eaten into. Slender, tough-skinned, brownish, polished-looking worms about 1 inch long, with chewing mouth parts and six short legs, are found in seeds or in soil near-by. *Wireworms*, p. 432.

Pea Moth[1]

Importance and Type of Injury.—In eastern Canada, Michigan, Wisconsin, and possibly other states, growing peas within the pod have irregular cavities eaten out of the side, seldom exceeding half of their substance, by a yellowish-white caterpillar up to ½ inch long with both extremities of the body darker, and small dark spots and pale short hairs scattered over the body. The presence of the worms is not easily detected except by opening the pods, when the seeds are seen to be spoiled and the pod partially filled with the pellets of excrement and silk of the caterpillars (Fig. 295). Affected pods yellow, or ripen prematurely.

Plants Attacked.—No food plants are known except varieties of field and garden peas.

Distribution.—The insect has been present in America only since about 1900, and has so far confined its damage largely to eastern Canada, Michigan, and Wisconsin.

Life History, Appearance, and Habits.—Winter is passed as inactive larvæ enclosed by strong cocoons of fine silk, about ⅜ inch long and covered with soil particles. These are found a short distance below the surface of the soil in the fields. Others

[1] *Laspeyresia nigricana* Stephens, Order Lepidoptera, Family Eucosmidæ.

winter in similar cocoons in cracks and crevices about the barns where the peas were stored before threshing. They change to brownish pupæ in late spring.

About the time peas come into blossom (latter half of July in northern Wisconsin) the adults appear from the cocoons. They are frail, very small moths, about ½ inch across the spread wings, of a general brown color with short black-and-white oblique lines along the front margin of the forewings. They may be found zigzagging about the plants in late afternoon, mating and laying eggs, but not themselves injuring the peas. The eggs are white, flattened, and a little smaller than an ordinary pinhead. They are deposited one in a place upon the pods, leaves, or stems of the peas, and on other plants growing in the pea fields. Promptly upon hatching, the minute caterpillars drill into the pods, casting out a little frass, which however soon blows or wears away, leaving almost no indication of their entrance. Within 2 to 4 weeks they are full-grown, when they eat out of the pods and enter the soil or other protected places mostly during August. Here they form the winter cocoons, in which they remain during the next 10 months.

Fig. 295.—Work of the pea moth. (*From Wis. Agr. Exp. Sta. Bull.* 310.)

Control Measures.—Fluke, working in Wisconsin, suggested threshing promptly within a day or two of harvesting, so that larvæ still in the pods might be killed by the thresher; burning all remnants of the crop; and thorough disking of the soil after harvesting; deep plowing in the fall to destroy the larvæ in their winter nests; and the use of early varieties, maturing before mid-July, in Wisconsin.

References.—*Wis. Agr. Exp. Sta. Bull.* 310, 1920; *Proc. Ent. Soc. Nova Scotia for* 1919, pp. 11–20, 1920.

Mexican Bean Beetle[1]

Importance and Type of Injury.—Where it occurs, this insect is a serious enemy of all kinds of snap beans and Lima beans. Both larvæ and adults feed on the leaves, usually on the under surface, leaving the upper surface more or less intact except as it breaks through upon drying out. The larvæ eat out somewhat regular areas, leaving slender parallel strips of untouched leaf between them. When abundant, the insects also attack the pods and stems, and the plants may be shredded and dried out so that they die within a month after the attack begins, often before any crop is matured.

Distribution.—For three-quarters of a century, the Mexican bean beetle, also known as the bean lady beetle, was a more or less serious pest only in the western part of the country, from Colorado southward. In 1920 it was discovered in northern Alabama, having been shipped

[1] *Epilachna corrupta* Mulsant, Order Coleoptera, Family Coccinellidæ.

there, it is believed, in alfalfa hay a year or two earlier. By 1928, it had spread over an oval area centering about eastern Tennessee and covering parts or all of the following districts: Mississippi, Alabama, Georgia, North Carolina, South Carolina, Tennessee, Kentucky, Virginia, West Virginia, Pennsylvania, New York, Ohio, Indiana, Michigan, and Ontario. Further spread is sure to occur, and in time its range will probably extend over almost the entire country.

Plants Attacked.—All kinds of garden beans, and cowpeas, soybeans, and beggar-tick. It has been most injurious to garden and field beans and occasionally to soybeans and cowpeas. In cases of extreme infestation, alfalfa, clovers, vetch, and some grasses and weeds are fed upon.

Life History, Appearance, and Habits.—This insect passes the winter only in the adult stage, occurring on the ground among leaves and other

FIG. 296.—Mexican bean beetle; showing eggs, larvæ, pupa (above), and adults on bean leaves, about natural size. (*Modified from Tenn. State Board of Entomology.*)

rubbish, sometimes in groups and mostly near the fields where beans were grown. The beetles (Fig. 296) are from $\frac{1}{4}$ to $\frac{1}{3}$ inch long, very convex, short ovate in outline, and from yellow to coppery brown in color. Each wing cover has eight small black spots that form three rows across the body when the wings are at rest. The general appearance is similar to that of our common beneficial lady beetles (see p. 57), but it is larger than most of them. Some of the beetles appear in gardens and fields of beans about the time the earliest garden beans are coming up from the seed, while others continue to straggle out of winter quarters for nearly 2 months. After feeding a week or two on the beans, the adults deposit eggs on the underside of the leaves. These are about $\frac{1}{20}$ inch long, orange yellow in color, and fastened on end in close groups of 40 to 50 or more. The eggs hatch in a week or two, depending on the temperature, and the larvæ feed as already described from 2 to 5 weeks. When full-

grown, they are 1/3 inch or more in length, by half as broad, oval, yellow, and have their backs protected by six rows of long branching, black-tipped spines (Fig. 296). When growth is completed, the larvæ cement the hinder part of their bodies to the underside of uninjured leaves of beans or other plants, often gathering in groups. The pupa (Fig. 296) pushes out of the larval skin crowding it back to the tip of the abdomen which remains covered with this spiny wrinkled skin. The exposed part of the pupa is nearly bare, smooth, orange-yellow and rounded in front. The adult emerges in about a week, and may lay eggs for the second generation within 2 weeks more. From egg to adult occupies a month, on the average, and in the southeastern states there are three or even four partial generations. In the western and northern states there is one generation, with a partial second. Most injury occurs in July and August. Dispersal takes place chiefly in late summer by the flight of the adults, and during the autumn months, when the beetles gradually leave the plants and seek hibernating places.

Control Measures.—Any one of the following insecticides applied to the foliage of beans *so as to cover the underside of the leaves thoroughly* will protect the crop if applied every 10 days, beginning as soon as the beetles and their eggs become numerous on the plants.

(*a*) Spray with magnesium arsenate, 1 pound to 50 gallons of water, using about 100 gallons to the acre; or (*b*) dust with a thorough mixture of calcium arsenate 1 pound, fine dusting sulphur 1 pound, and hydrated lime 4 pounds, using 12 to 15 pounds to the acre; or (*c*) dust with 1 part calcium arsenate in 9 parts hydrated lime; or (*d*) dust with a thorough mixture of magnesium arsenate 1 pound and hydrated lime 4 pounds, using 12 to 15 pounds to the acre. Dusting with sodium fluosilicate at the rate of 1 part in 2 parts of lime has given fairly satisfactory control.

Where the beetles are abundant, it is recommended that bush beans be grown instead of pole beans, that no larger acreage be planted than can be properly sprayed or dusted, and that the remnants from crops of green beans be plowed under as soon as the crop is harvested. In the North, late-planted beans will escape the overwintered females, and thus avoid considerable injury.

References.—*U. S. Dept. Agr. Farmers' Bull.* 1407, 1924; *U. S. Dept. Agr. Dept. Bull.* 1243, 1924; *Jour. Econ. Entomol.*, Vol. 21, p. 178, 1928.

Bean Leaf Beetle[1]

Importance and Type of Injury.—Injury by the bean leaf beetle is twofold: the reddish to yellowish, dark-spotted, adult beetles feed on the underside of the leaves, eating round holes in them; while the slender white larvæ chew the roots and feed on the stem just below the surface of the soil, more or less completely girdling the plant.

Plants Attacked.—Beans, peas, cowpeas, soybeans, corn, beggar-tick, bush clover, tick trefoil, hog peanut, and other weeds.

[1] *Ceratoma trifurcata* Forster, Order Coleoptera, Family Chrysomelidæ.

Distribution.—Abundant in the Southeastern States and ranging north to Kansas, Minnesota, Canada, and New York, and westward to Texas and New Mexico.

Life History, Appearance, and Habits.—Winter is passed in the adult stage, in or near bean fields of the preceding season, and the beetles are ready to attack the plants as soon as they appear above ground. The adults (Fig. 297, *a*) vary much in color and markings, but are typically reddish to yellowish in color, about 1/6 inch long with three black spots in a row along the inner edge of each wing cover and a black band all around near the outer margin of the wing covers. They are found on the underside of the leaves and when disturbed generally drop. The females descend to the ground to lay their eggs in the soil about the bases of the plants. The yellowish eggs are found in small clusters of a dozen or two and each female may lay 40 or more such clusters during a period of about a month. The eggs hatch in from 1 to 3 weeks, depending upon the season, and the slender white larvæ find their way to the base of

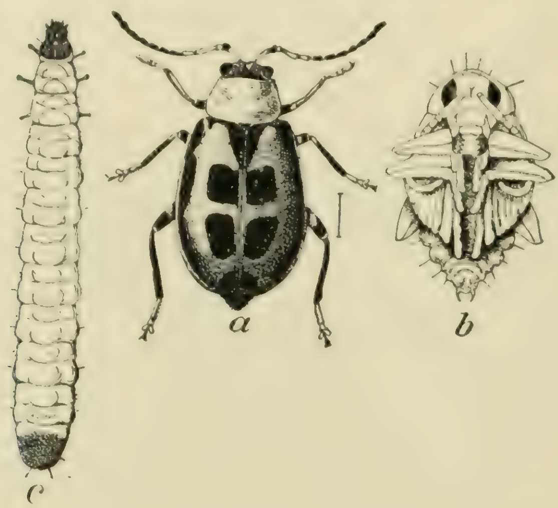


FIG. 297.—Bean leaf beetle. *a*, adult; *b*, pupa; *c*, larva. Line indicates natural size of beetle. (*From U. D. S. A. Farmers' Bull.* 856.)

the stem or roots and feed, as described above, for 3 to 6 weeks. The larvæ (Fig. 297, *c*) are whitish, dark brown at both ends, conspicuously segmented, and have six very small legs near the head. When full-grown, the larva forms an earthen cell within which the white, soft-bodied pupa stage (*b*) is completed in about a week. In the North these adults constitute the overwintering population. In the South there are one or two partial generations in addition.

Control Measures.—Where this insect has been destructive, applications of the arsenicals recommended for the control of the Mexican bean beetle (see p. 453) should be made to the vines as soon as the beetles appear on them, to catch the females before they have laid their eggs. Especial care should be taken to cover the undersides of the leaves. The destruction of the wild host plants, such as beggar-tick, hog peanut, tick trefoil, and bush clover, will tend to prevent abundance of the pests.

References.—*U. S. Dept. Agr. Bur. Ent. Bull.* 9, 1897; *Jour. Econ. Entomol.*, Vol. 8, p. 261, 1915.

SPOTTED CUCUMBER BEETLE

This general pest often eats large irregular holes in the foliage of beans and cuts off the growing tips. When the leaves are parted, the yellowish-green, black-spotted adults drop or fly away. The stems of the plants are often girdled by the feeding of many beetles at or near the surface of the ground so that the plant gradually dies.

The insect is further discussed under Corn, as the southern corn rootworm (p. 311), and under Cucurbit Crops (p. 461). A thorough application of an arsenical such as recommended for the Mexican bean beetle will control this insect on beans. Since the insects are repelled by the taste of arsenicals, it is well to leave a few plants at intervals throughout the patch unsprayed, upon which the beetles may congregate, otherwise they may concentrate about the base of the plants where the spray has not reached and do very severe injury

Pea Aphid[1]

Importance and Type of Injury.—Peas, after having made a good start, may be checked and gradually wither or shrivel, turn yellow, and

Fig. 298.—Pea aphids on stems of clover, natural size. (*From Ill. State Nat. Hist. Sur.*)

in bad cases shed their leaves and die. Upon a brushing or shaking of the plants, small green insects, the largest of them only ⅙ inch long, fall to the ground. If the plants are examined, the terminal shoot and leaves and the stems may be found crowded or lined with myriads of these green, long-legged, either winged or wingless aphids (Fig. 298), which suck the sap and possibly also poison the plant. When the aphids are abundant, their shed skins give the plants and the ground a

[1] *Illinoia pisi* (Kaltenbach), Order Homoptera, Family Aphididæ.

whitish appearance. When the insects are not abundant enough to kill the plants or even to cut the yield greatly, the quality of the peas is often affected. Canners often try to remedy this defect by adding more sugar when packing such peas. The aphids are often overlooked and the injury laid to the more conspicuous insects, especially lady beetles, that are feeding upon the aphids, or to disease, such as root rot.

Distribution.—Throughout the United States except possibly some of the Rocky Mountain States.

Plants Attacked.—Garden and field peas, sweet peas, clover, sweet clover, alfalfa, and weeds of the legume family.

Life History, Appearance, and Habits.—This aphid winters on alfalfa, clovers, especially red and crimson clover, and other perennial plants. It may go through the winter either in the egg stage or as ovoviviparous

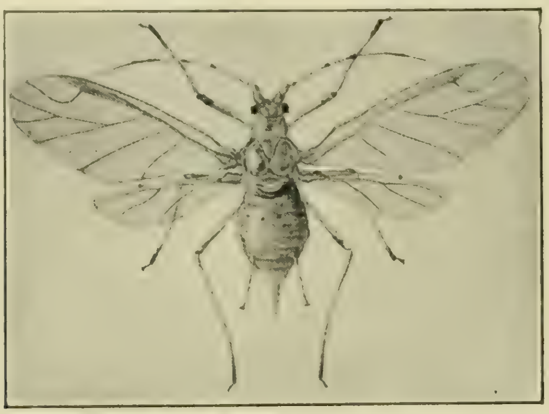


FIG. 299.—Winged, ovoviviparous female adult of the pea aphid. (*From Ill. State Nat. Hist. Sur.*)

females in the northern states and, farther south, may continue to breed all winter on these and other plants. In the spring it increases on the winter-host plants and in the latitude of central Illinois winged migrants begin to spread to other plants, including peas, about May 1. These winged females (Fig. 299) start colonies on new plants by giving birth to active young nymphs which molt four times, reach the adult stage, and begin reproducing in about 12 days. Each female commonly produces 6 or 7 young a day until from 50 to 100 or more have been born. There are from 7 to 20 or more such generations of females in the course of a year. When unchecked by natural enemies their increase is phenomenal, but they are much subject to fluctuations due to weather conditions, the attacks of many predators and parasites, and fungous diseases. They usually become most abundant and injurious to peas during June, in the latitude of Illinois. Most of the adults are wingless, but when they become crowded on the plant some winged ones appear and these spread the insect widely. During midsummer they are found chiefly on other leguminous plants, but in early fall again become abundant on peas wherever these are available.

As the amount of daylight diminishes in the fall and the temperature drops, the ovoviviparous females give birth to young some of which become sexually mature, egg-laying, wingless females and others winged males. The eggs are laid chiefly on the leaves and stems of alfalfa and red clover and are about $\frac{1}{30}$ inch long, light green in color when newly laid but turning a shiny black. These fertilized eggs live over winter and give rise in the following spring to the ovoviviparous stem-mothers which start the next season's infestations.

Control Measures.—Nicotine dust containing 2.4 per cent nicotine or 6 per cent nicotine sulfate, used at the rate of 30 pounds to the acre, is fairly effective, especially if a sheet of canvas about 20 feet long is

FIG. 300.—Four-row traction duster equipped with "trailer" to hold the fumes from nicotine dust. (*From U. S. D. A. Farmers' Bull.* 1499.)

dragged along as a trailer after the duster to confine the fumes from the dust for a few seconds (Fig. 300). According to Dudley, this method is most effective when the temperature is 75° F. or higher, and in the absence of wind.

An aphid-collecting machine called an aphidozer which brushes off and collects the plant lice has been devised by Dudley. The machine consists of a revolving reel fitted with specially made brushes which brush and knock the aphids from the plants into a hopper from which they can be removed at intervals and destroyed. In the present stage of its development, however, the aphidozer is not recommended for practical use.

References.—*U. S. Dept. Agr. Dept. Bull.* 276, 1915; *Md. Agr. Exp. Sta. Bull.* 261, 1924.

C. INSECTS INJURIOUS TO CUCURBITS

FIELD KEY FOR THE DETERMINATION OF INSECTS INJURING CUCUMBER, SQUASH, MELONS AND OTHER CUCURBITS

A. *Insects eating holes in the leaves or chewing at the stems:*

1. Small beetles, about 1/5 inch long, with three black stripes down the back, separated by wider stripes of bright yellow, eat irregular holes in the leaves and feed especially about the base of the stem, often girdling the plant at or near the surface of the ground. *Striped cucumber beetle*, page 459.

2. Beetles of the same general shape but slightly larger than *A* 1, and green or greenish-yellow in color and with six conspicuous black spots on each wing cover, attack especially the leaves and flowers of the plants. *Spotted cucumber beetle*, page 461.

3. Leaves have small rounded holes eaten into them so they look as though peppered with fine shot. Very small black beetles about 1/16 inch long, or larger ones 1/8 inch long, with a broad yellow longitudinal stripe on each wing cover, are found mostly on underside of leaves, jumping vigorously when disturbed. *Flea beetles*, page 437.

4. Stems of young plants are chewed or cut off near or below the ground, by dull-greenish, brownish, or grayish, cylindrical, "greasy-looking" worms, variously marked with spots, stripes, or oblique bands; the largest ones 1½ inches long; found in the soil during the day; often coil up when disturbed. *Cutworms*, page 434.

B. *Insects sucking sap from the leaves or stems, causing wilting, curling, and dying of leaves:*

1. Elongate, flattened, oval, blackish-brown bugs, ⅔ inch long; and powdery-white, black-legged nymphs, from 3/16 to ½ inch long, hiding under wilted leaves, clods, etc., or shying about the vines, suck the sap and poison the plants. Have a stinking odor when crushed. *Squash bug*, page 462.

2. Developing leaves at tips of vines are curled, wilted, and shriveled, the undersides thickly dotted with small, winged or wingless, tan, brown, green, or black aphids of various sizes, which suck out the sap. *Melon aphid*, page 464.

C. *Insects boring through the center of the vines causing extensive wilting and rotting of the stem:*

1. Yellowish, sawdust-like excrement accumulates in small masses from holes in the vines. Within the vine are found whitish, grub-like caterpillars up to 1 inch long and ¼ inch in diameter, with brown heads and short legs. *Squash vine borer*, page 466.

2. Injury similar to *C* 1, especially late in the season, caused by a smaller and slenderer green worm, not over ¾ inch long, the smaller ones with a row of black spots across each segment. *Pickle worm*, page 468.

D. *Insects boring into the fruits:*

1. Greenish to yellowish, brown-headed caterpillars, up to ¾ inch long, those under ½ inch with conspicuous cross rows of blackish spots, bore into fruits of muskmelon, cucumber, and squash, pushing out a small mass of excrement behind them and causing the fruits to rot and sour. *Pickle worm*, page 468.

2. Injury very similar to *D* 1 is caused by a larger, more slender worm, ranging up to 1¼ inches long, greenish yellow in color, with light-brown head and two long, whitish, well-separated stripes down the back. They wriggle very actively when disturbed. *Melon worm*, p. 470.

3. Plain green, or greenish, black-spotted, or yellow and black-striped beetles, about 1/5 inch long, gnaw into the rind of squashes, pumpkins, melons, and related fruits in the fall of the year, often working together in great numbers. They disfigure

the fruits but seldom penetrate deeply enough to cause rotting or fermentation. *Striped and spotted cucumber beetles and northern corn rootworm*, pages 461 and 310.

E. Insects attacking the roots and boring in the underground stem, or devouring the planted seeds:

1. Very slender, whitish worms, the largest ⅓ inch long, with the two extremities brown, with six short legs behind the head and a pair of blunt prolegs on the last segment, devour the smaller roots and tunnel through the underground stems and larger roots. Larvæ of *striped cucumber beetle*, page 459.

2. Thick, white, soft-bodied grubs up to an inch or more long, with reddish-brown heads, six slender legs, and body somewhat slenderer near the middle, chew the roots. Lie curled in a "*U*" or semicircle. *White grubs*, page 433.

3. Slender, tough, smooth, brown worms up to 1 inch long, with chewing jaws and six small legs, eat into seed before or as it germinates and later chew at the roots and underground parts of the stem. *Wireworms*, page 432.

Striped Cucumber Beetle[1]

Importance and Type of Injury.—This is the most serious pest of cucurbits throughout America east of the Rocky Mountains. On the Pacific Coast, a distinct but very similar species, the Western cucumber beetle,[2] is the cause of a similar injury and may be controlled in the same way. The beetles work on the plants from the moment they appear above ground in the spring until the last remnants of the crop are removed or destroyed by frost. They work down to meet the germinating plants before they reach the surface of the soil. They chew the leaves and tender shoots, and especially the stem near or below the surface, partially or completely girdling it. They feed in the blossoms, and, in autumn especially, gnaw holes in the rind of the fruits. They are known carriers of the bacterial wilt of cucurbits, the bacillus[3] causing this disease living over winter in the intestines of this and the related spotted cucumber beetle. In the spring the beetles inoculate the disease into the interior tissues of the new plants as they feed, and spread it from plant to plant and field to field wherever infective beetles go and feed. This insect is also one of the most important agencies in the spread of cucumber mosaic. Furthermore, the larvæ of the beetle injure the vines during the summer by devouring the roots and tunneling through the underground parts of the stems. Many plants are killed early in the season by this beetle and the wilt disease it spreads, and such vines as survive the first attack have the yield greatly reduced by the work of the adults and larvæ.

Plants Attacked.—Cucumbers, muskmelons, winter squashes, pumpkins, gourds, summer squashes, and watermelons appear to be injured about in the order named. So far as known the larvæ can develop only on these and related cucurbits. The beetles, however, also feed on

[1] *Diabrotica vittata* Fabricius, Order Coleoptera, Family Chrysomelidæ.

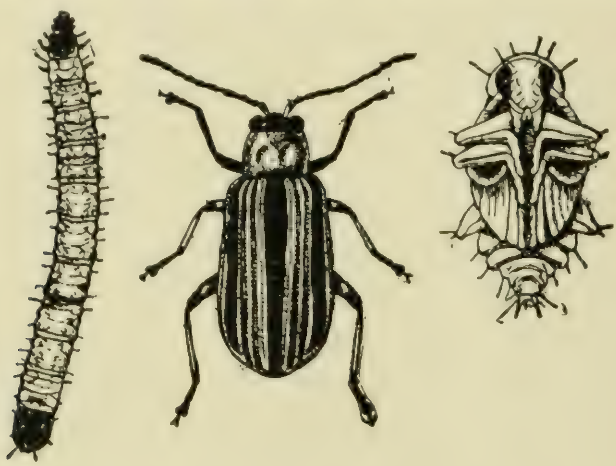
[2] *Diabrotica trivittata* Mannerheim.

[3] *Bacillus tracheiphilus* Erm. Sm. (see *U. S. Dept. Agr. Dept. Bull.* 828, 1920).

beans, peas, and corn, and the blossoms of many other cultivated and wild plants.

Distribution.—This native insect ranges from Mexico into Canada, east of the Rocky Mountains.

Life History, Appearance, and Habits.—Only the adult stage of these beetles lives through the winter. Their hibernating quarters seem not to be well known, but according to Dr. W. V. Balduf, they winter over on the ground under protecting trash of various kinds, crawling under any convenient shelter near their last feeding place when cold weather arrives. This may be either near the previous crop or about their wild food plants, such as goldenrod and asters. The beetles emerge from hibernation very early, becoming active at temperatures above 55° F.,



b a c

FIG. 301.—The striped cucumber beetle. *a*, adult; *b*, larva; *c*, pupa; about five times natural size. (*After Chittenden, U. S. D. A.*)

and, before cucurbits are available for them to feed upon, subsist on the pollen, petals, and leaves of hawthorn, thorn apple, apple, elm, syringa, and related plants for several weeks. As soon as cucumber, squash, or melon vines appear above ground, they come to these plants, settling upon the young vines and devouring the seed leaves and the stems. The beetles (Fig. 301, *a*) are familiar to nearly every grower. They measure about $\frac{1}{5}$ inch long by $\frac{1}{10}$ inch wide. The upper surface is about equally black and yellow, the wing covers with three longitudinal black stripes. Mating and egg laying take place soon after the beetles migrate to the vine crops. The orange-yellow eggs are laid about the base of these plants, often below the surface of the soil or in cracks in the ground. The larvæ (*b*) that hatch from them work their way into the soil and feed for from 2 to 6 weeks on the roots and underground parts of the stem, frequently entirely destroying the root system. When full-grown they are about $\frac{1}{3}$ inch long by one-tenth as broad. The whitish pupa stage (*c*) is also found in the soil and lasts for about a week. Adults from this first generation appear in midsummer over a period of 6 weeks

or more and feed extensively on stems, leaves, and blossoms of cucurbits, and also on legumes. In the warmer latitudes these beetles soon mate and produce another generation during late summer and early fall, and the adults from these and even from partial third or fourth generations are the ones found in late fall on goldenrod, sunflower, and aster blossoms and on the fruits of cucurbits. In the northern states there is only one generation.

Control Measures.—This pest is hard to control because of the underground position of the larvæ, the habit of the adults of attacking the plant low down or even below ground, and the fact that the adults detect arsenicals on the plants and seek out places that are not covered by these poisons, on which to feed. The most successful control, in our experience, is a repellent and poisonous dust recommended by the Ohio Experiment Station and consisting of 1 part calcium arsenate and 20 parts burned gypsum or land plaster thoroughly mixed and dusted over the plants often enough to keep them covered from the time they appear through the ground until the attack by the first generation beetles is over. A special grade of dusting gypsum can be obtained for this purpose. The U. S. Department of Agriculture recommends a dust containing 5 per cent of 40 per cent nicotine sulphate (2 per cent nicotine) in hydrated lime or in a mixture of kaolin and lime, using about ½ ounce to the hill. See page 241 for method of preparing nicotine dusts. This material is said to act both as a repellent and as a contact insecticide. Three years' experiments in Illinois have invariably given greater yields where the calcium arsenate-gypsum mixture was used than where cucumbers were dusted with nicotine sulfate in hydrated lime.

Where the acreage is small enough to make it practicable, the plants may be covered, from the moment they appear through the ground, with wire or cloth screen made in the form of cones or hemispheres. Such protectors keep the beetles off until the plants get a good start, when they must be removed. It is well to plant an excess of seed, and thin out after the plants are started.

References.—*Ohio Agr. Exp. Sta. Bull.* 388, 1925; *U. S. Dept. Agr. Farmers' Bull.* 1322, 1923; *Wis. Agr. Exp. Sta. Bull.* 355, 1923.

Spotted Cucumber Beetle[1]

This species belonging in the same genus as the striped cucumber beetle and the northern corn rootworm, is a much more general feeder than either. While the total damage done by it, because it also injures field crops, is probably greater than either of the others, its injury to cucurbits is much less noticeable. This injury is similar to that of the striped cucumber beetle. The larva of this insect is the well-known

[1] *Diabrotica duodecimpunctata* Olivier, Order Coleoptera, Family Chrysomelidæ.

southern corn rootworm. In addition, the adult is a constant pest of string and Lima bean, pea, potato, beet, asparagus, eggplant, tomato, cabbage, and many other garden plants, and the larvæ develop on the roots of corn, beans, small grains, alfalfa, and many wild grasses. A fuller description of the insect is given under corn insects, Southern Corn Rootworm, page 311. On curcurbits it may be controlled with the calcium arsenate-gypsum mixture, as recommended for the striped cucumber beetle.

Squash Bug[1]

Importance and Type of Injury.—There is no more vexatious pest of the garden than the squash bug. Leaves of plants attacked by it rapidly wilt as though the sap flow had been cut off or poisoned, and soon become blackened, crisp, and dead. Small plants may be killed entirely; larger plants usually show certain leaves or runners that are affected. In many localities it is practically impossible to grow certain varieties of squashes, as the plants are killed by these bugs before any fruits are matured. The bugs possess a remarkable vitality and tenacity of life, to the great annoyance of the gardener. Plants in farm or city gardens suffer most severely although large commercial plantings also are badly injured.

The attack of this pest may be identified by finding the brownish-black adult bugs, about 2/3 inch long (Fig. 302, *a*), and their numerous, whitish, black-legged nymphs (*c*, *d*, *e*), which range in size from 3/16 to 1/2 inch long. They are usually more or less hidden about the base of the plant under the deadened leaves or under clods, and when approached they shy around the vines or walk rapidly to cover.

Plants Attacked.—All of the cucurbits or vine crops are attacked, but the bugs show a marked preference for squashes and pumpkins. Among the squashes, the winter varieties, such as hubbards and marrows, suffer most severely.

Distribution.—Throughout the whole United States from Central America to Canada.

Life History, Appearance, and Habits.—Only the unmated adult bugs pass the winter. They hibernate in all kinds of shelter under the protection of dead vines, leaves, clods, stones, piles of boards, outbuildings, and dwellings which they enter in the fall. They are rather slow to appear in spring and feed only on cucurbits. By the time vines begin to "run," the adults fly into the fields and gardens and apparently locate their food by the odor of the plants. Mating occurs in the spring and egg laying begins soon afterward. The egg clusters (Fig. 302, *b*) will usually be found on the under side of a leaf in the angle formed by the veins. The eggs are brownish, from yellowish brown to very dark bronzy brown according to their age, oval in outline, and about 1/16 inch long. They are laid in

[1] *Anasa tristis* De Geer, Order Hemiptera, Family Coreidæ.

groups commonly numbering a few dozen. The eggs lie on their sides, sometimes close together, sometimes separated by more than their own diameter. They are usually placed in rows in two directions, the rows meeting each other at an acute angle. The overwintering adults live and continue laying eggs until about midsummer.

A week or two after the eggs are laid, the small nymphs hatch. They are at first strikingly colored, the abdomen being green, the head, thorax, antennæ and legs crimson, soon darkening to reddish brown. The older nymphs are grayish white in color, with nearly black legs and antennæ. There are five nymphal stages. When the insects are crushed, a disagreeable odor is given off from two oval spots on the middle of the upper side of the abdomen. This gives rise to the name "stink bug" often wrongly

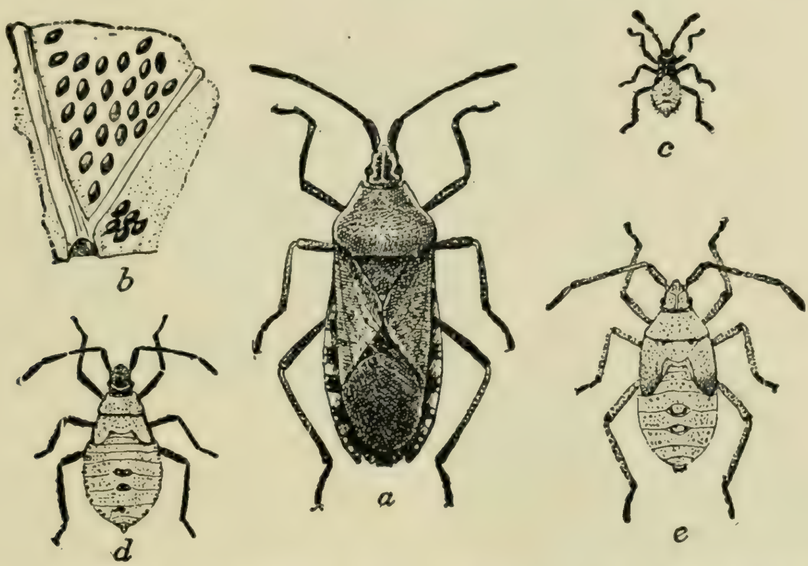


FIG. 302.—Life stages of the squash bug. *a*, adult; *b*, eggs (about natural size); *c*, *d* and *e*, nymphs in different stages. *a*, *c*, *d*, and *e* twice natural size. (*From Chittenden, U. S. D. A.*)

applied to these insects.[1] All stages of the bugs feed by sucking the sap of the plant. The youngest nymphs are gregarious, those from one egg cluster feeding close together.

From 1½ to 2 months after the eggs are laid, the new bugs begin to transform to adults, there being usually a period of scarcity of mature bugs following the disappearance of the parents, before the young have become adult. The new adults do not mate or lay eggs until the following spring, at least in the North, and there is probably only one generation a year throughout the country. These adults and the nymphs from later-laid eggs are usually present in great numbers when the first frosts kill the leaves and vines. The bugs then collect in dense groups upon the protected faces of unripe fruits, where they continue to suck the sap. They gradually fly and crawl away in search of winter shelter, and such

[1] The true stink bugs are the shield-shaped bugs of the related family Pentatomidæ.

nymphs as do not succeed in reaching the adult condition die during the early winter.

Control Measures.—No satisfactory control measure for squash bugs has ever been discovered. The adult bugs are so resistant to contact sprays and poison gases that the use of known insecticides is impracticable. The young bugs may be killed by a spray of nicotine sulphate 1 to 400 of soapy water, by certain oil sprays, or by fish-oil soap ¼ pound, and sulphur 2 ounches, to each gallon of water, applied very forcibly to the nymphs; but it is almost impossible to reach all of them. One of the most effective controls known is to collect the bugs by hand and to crush the egg masses as fast as they appear on the young plants in spring. Pieces of boards, shingles, and similar flat objects are often placed out among the plants. The bugs collect under them at night and if they are examined each morning many may be destroyed. In the fall, great numbers of the bugs can be caught and killed on the fruits after the vines have died. As soon as the crop is harvested, the vines should be removed from the field and burned or worked into a compost heap. The margins of fields and the grounds surrounding the garden should be as free as possible of rubbish, piles of leaves, boards, and other shelter for the bugs during the winter.

References.—*N. H. Agr. Exp. Sta. Bull.* 89, 1902; *Jour. Econ. Entomol.*, Vol. 13, pp. 416–425, 1919, and Vol. 16, p. 73, 1923.

Melon Aphid[1]

Importance and Type of Injury.—After the vines of cucurbits begin to "run," a single hill here and there will often be found to have the edges of the leaves curled downward or some of them wilted, shriveled, and browning (Fig. 303). The under sides of such leaves, inside the curl, are generally crowded with very small, yellow, green, and black aphids, some winged, others wingless, and of several sizes. These insects suck the sap from the leaves, weakening the plants and reducing both the quantity and quality of the fruit. In years of abundance, they kill the plants and ruin the crops over extensive areas. In the North they are especially destructive in hot, dry summers, following cool, wet springs which have reduced the efficiency of their natural enemies. Chittenden considered this the most destructive aphid occurring in this country.

Plants Attacked.—This insect feeds on a wide variety of plants, but is of economic importance chiefly on the cucurbits, cotton (on which it is a very serious pest), okra, and citrus fruits. It also feeds on strawberry, bean, beet, spinach, eggplant, asparagus, a number of ornamental plants, and many weeds, especially shepherd's purse, pepper grass, pigweed, and dock. It also occurs on certain of these plants in the greenhouse.

[1] *Aphis gossypii* Glover, Order Homoptera, Family Aphididæ.

Distribution.—Throughout the United States, southward to Central and South America; most destructive in the South and Southwest.

Life History, Appearance, and Habits.—In the North, according to Dr. Edith M. Patch, the insect winters on live-forever, in the egg stage, where this plant is found. These eggs are fertilized, in the fall, by males that developed on the same plant. In the extreme South, at least,

Fig. 303.—Tip of a melon vine badly infested with melon aphids. (*From Chittenden, U. S. D. A.*)

the insect continues breeding ovoviviparously throughout the winter. It appears on cucurbits in late spring or early summer, and, if the weather is favorable and it is not checked by sprays or natural enemies, increases and spreads with astonishing rapidity. Paddock records 51 generations in 12 months in Texas, the average young per female being more than 80. Many winged individuals are produced, and wherever they fly or are blown by the wind a new colony is soon started.

Control Measures.—Since the attack on cucurbits commonly begins in small, scattered spots over the field, such spots should be watched for and the aphids destroyed upon them before they become generally established over the whole crop. Besides the wilting, curled leaves, attention may be attracted to the aphids early by the visits of ants, bees, wasps, and flies to the colonies to get the honeydew and by the white cast skins of the aphids sticking to the leaves. Every effort should be made to apply control measures before the leaves on the terminal shoots curl too badly. A 3 per cent nicotine dust, made according to the directions given on page 241 is the most effective insecticide for these aphids on the vine crops. Dusting is much more effective if the plants are covered with a piece of canvas or tarpaulin beneath which the dust is applied. The tarpaulin should be left in place for 3 to 5 minutes. Nicotine sulphate 40 per cent, used 1 to 800 in soapy water kills all the aphids wetted by it, but it does not cover as well as the dust, which may penetrate even to the interior of curled leaves. Whenever a Bordeaux mixture is being applied for fungus diseases, ½ pint of nicotine sulphate may be added to each 50 gallons of this spray to destroy these aphids if they are present.

References.—*U. S. Dept. Agr. Farmers' Bull.* 1499, 1926; *Tex. Agr. Exp. Sta. Bull.* 257, 1919; *Ill. Agr. Exp. Sta. Circ.*, 297, 1928; *U. S. Dept. Agr. Farmers' Bull.* 1282, 1922; *Me. Agr. Exp. Sta. Bull.* 326, 1925.

Squash Vine Borer[1]

Importance and Type of Injury.—This pernicious borer is in many localities a very destructive pest of squashes and pumpkins, sometimes destroying 25 per cent or more of the crop. Attention will often first be called to it by the sudden wilting of a long runner or an entire plant. Examination of the wilted vine will reveal masses of coarse, greenish-yellow excrement which the borer has pushed out of the vine through holes in the side. If such a vine is split open it will be found hollowed out and partly filled with moist slimy frass similar to that cast out on the ground. In the midst of this material is a thick, white, wrinkled brown-headed worm, the largest ones 1 inch long and almost ¼ inch thick (Fig. 304, *d*). Plants injured to the point of wilting usually contain a number of borers. Their excrement should be watched for especially about the base of the plant close to the roots. Infested vines are often completely girdled, and usually become rotten and die beyond the point of attack.

Plants Attacked.—Squashes, such as hubbards, marrows, cymblings, and other late varieties, summer squash, pumpkins, gourds, cucumbers, and muskmelons are injured, about in the order named. The wild cucumber also is infested.

Distribution.—East of the Rocky Mountains from Canada to South America.

[1] *Melittia satyriniformis* Hübner, Order Lepidoptera, Family Ægeriidæ.

Life History, Appearance, and Habits.—The insect winters an inch or two below the surface of the soil inside of a tough, dirt-covered, silk-lined, black cocoon (Fig. 304, *e*) about ¾ inch long, either in the larva or pupa stage. If as a larva, the change to the mahogany-brown pupa (*f*) occurs in the spring. Two or three weeks later, about the time the vine crops are beginning to run, the pupa tears open the end of its cocoon and wriggles up through the soil to the surface. Its skin then splits down the back and reveals a beautiful wasplike moth, 1 to 1½ inches across the wings (Fig. 304, *a*, *b*). The front wings are covered with metallic-shining

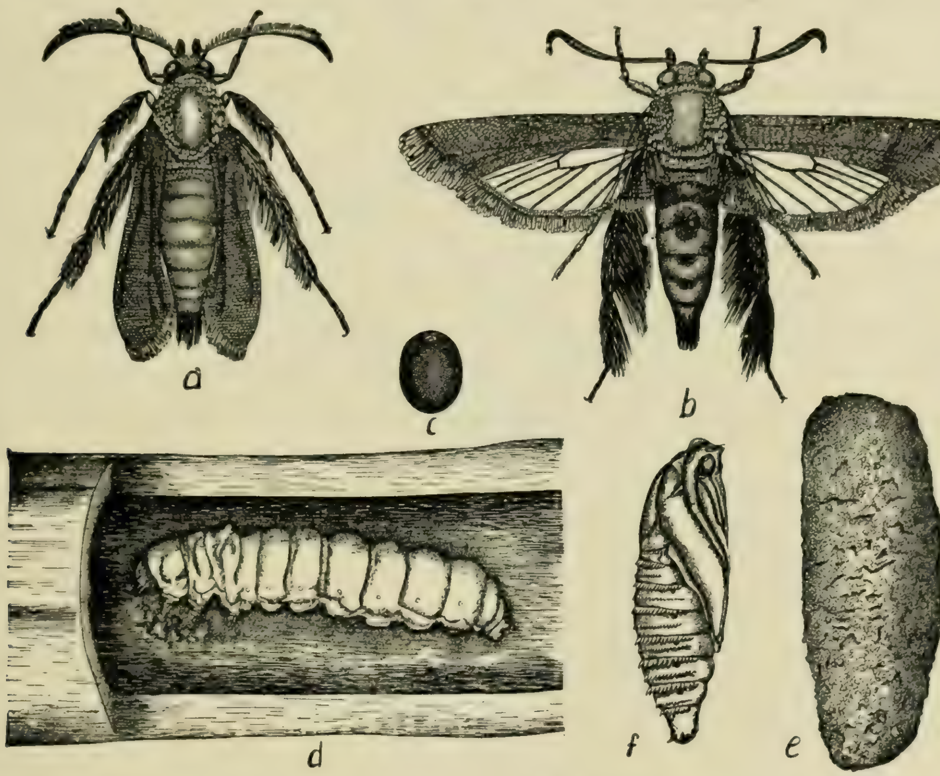


Fig. 304.—The squash vine borer; *a*, male; *b*, female; *c*, egg; *d*, larva in stem; *e*, earth-covered cocoon; *f*, pupa; about twice natural size. (*From Iowa Agr. Exp. Sta. Circ.* 90.)

olive-brown scales, but the hind wings are transparent. The abdomen is ringed with red, black, and copper; and, like its relative the peach borer, the moth flies swiftly and noisily about the plants during the daytime, seeming more like a wasp than a moth. Small, oval, somewhat flattened, brownish eggs, $\frac{1}{25}$ inch long, are glued one in a place on the stems, especially toward the base of the plant. The small borers enter the stem a week or two later and tunnel along, eating out the inner tissues for about a month. They have a brownish head and six short slender legs on the thorax and five pairs of short prolegs. Small borers may often be found in the leaf stem but most of them occur toward the base of the plant. Later in the season they are often found throughout the stem, and even in the fruits. When the larvæ are full-fed, they desert their burrows and

make cocoons in the soil. In the more northern states the larvæ remain in these cocoons until spring before pupating, there being only one generation a year. Farther south, at least a part of the larvæ pupate promptly after leaving the plants, and some of these change to adults, giving rise to a second generation of larvæ during August and September. In the Gulf States, two generations is believed to be the rule.

Control Measures.—Like most borers, this insect presents great difficulties in control since no insecticides can reach the point of feeding. Worthley recommends spraying the squash vines, within a week after eggs are first seen, using 40 per cent nicotine sulphate at the rate of 1 part to 300 parts of water (1 ounce to 2½ gallons) plus ½ part (½ ounce) of caustic potash fish-oil soap. This spray kills the eggs and should be directed principally at the base of the vine. One treatment will usually suffice, if damp weather follows to stimulate root formation along the runners. Continued dry weather, however, may necessitate two, three, or four applications at weekly intervals to insure a crop. The only thing to do with infested plants is to slit the stems lengthwise at the point of attack, crushing or removing the borers and immediately covering the stems with moist earth. Since girdling is most likely to occur at the base of the plant, it is well to cover the vines with soil a few feet from the base so that they may form supplementary roots and save the vine in case it is cut off at its base. To reduce injury the following year, all vines should be raked together and burned as soon as the crop can be harvested. The soil should be harrowed in the fall and turned under deeply in the spring to prevent the emergence of adults from the cocoons.

References.—*U. S. Dept. Agr. Farmers' Bull.* 668, 1915; *Mass. Agr. Exp. Sta. Bull.* 218, pp. 70–80, 1923.

Pickle Worm[1]

Importance and Type of Injury—Throughout the Gulf States, ripening fruits of muskmelons, cucumbers, and squashes are bored into by a whitish to greenish caterpiller, up to ¾ inch long, brownish at the head end and the smaller ones with a transverse row of black spots on each segment. The larvæ push out a small mass of green sawdust-like excrement from their holes in the fruit. The fruits soon rot, sour, and mold after the interior has been exposed to the air by these burrows. Other larvæ work in the stems, terminal buds, and especially in the blossoms of squash. Late-maturing crops are frequently almost totally destroyed by these worms.

Plants Attacked.—Muskmelon, cucumber, and squash, are seriously injured; watermelon rarely; and pumpkin not at all.

Distribution.—Especially destructive in the southern states but occasionally so, as far north as Missouri, Illinois, Michigan, and New York. The insect is found from Canada to South America.

Life History, Appearance, and Habits.—The insect hibernates in the pupa stage surrounded by a thin cocoon of silk and usually in a roll of leaf from the food plant. The cocoons generally lie on the ground in or near the old food plants but are sometimes suspended on weeds and other plants near-by. A very small percentage of them

[1] *Diaphania nitidalis* Stoll, Order Lepidoptera, Family Pyralididæ.

survive the winter and the spring cultivation of the soil, and give rise in late spring (early June in North Carolina) to striking-looking moths a little more than 1 inch wide across the spread wings (Fig. 305). The two pairs of wings are margined with a band of yellowish brown, about 1/8 inch wide, and the body above is of the same color, with purplish reflections in certain lights; while a median spot on the front wings, and the basal two-thirds of the hind wings, are transparent yellowish white. The tip of the abdomen has a prominent rounded brush of long hair-like scales. The moths fly late at night and eggs are deposited in clusters of two to seven on the tender buds, new leaves, or stems. The larvæ work at first in the buds, blossoms, and tender terminals, and some of them complete their growth in the vegetative part of the plant. Many however, begin to wander about when they are partly grown, and find their way to the fruits. Several fruits, especially of muskmelon, may be entered and ruined by a single caterpillar before its growth is completed. When full-grown they are greenish or yellowish all over, except for the brown head and brown area just behind the head,

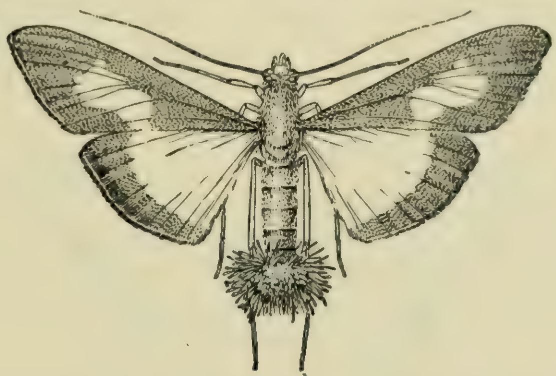


Fig. 305.—Adult of the pickle worm, twice natural size. (*From Crosby and Leonard "Manual of Vegetable-garden Insects," copyright, 1918, by the Macmillan Company. Reprinted by permission.*)

although younger larvæ are conspicuously marked with about 100 black spots evenly scattered over the body. After feeding for about 2 weeks, they desert their burrows, roll a leaf about themselves and spend the next week or 10 days in the pupa stage inside of a thin coccoon. The first generation is few in numbers, but the moths emerging from these pupæ in early July lay sufficient eggs so that the second generation may do some damage to early muskmelons. It is, however, during August and September that the really severe injury by this insect occurs, probably by the third or fourth generation larvæ. Muskmelons harvested before early July or mid-July are rarely injured. Four or five weeks are required for a generation, and, according to Smith, from whose account much of this description is drawn, there are four full generations and a partial fifth in North Carolina.

Control Measures.—After the worms begin to attack a crop, there is no known means of saving it. A few fruits can be enclosed in paper bags or placed on chips to avoid the worms, but for the commercial crop, protective measures must be taken during the preceding fall and spring. As soon as a crop is harvested, the vines and unused fruits and adjoining weeds and trash should be collected together and burned or converted into compost, to destroy the worms in them. Early in the fall the fields should be plowed in order to bury the pupæ that have fallen to the ground. Every effort should be made to get the crop matured early, since the early cantaloupes and cucumbers almost always escape. To protect muskmelons and cucumbers, early squash may be used as a trap crop. Four rows of squash to the acre are recommended by Smith, to be planted about 2 weeks after the main crop. Successive plantings every 2 weeks should be made, in order that there may be an abundance of

fresh squash blossoms throughout the season. The moths prefer to lay their eggs on squash, and the worms feeding in squash do not wander from fruit to fruit as those on other crops. Before the worms become full grown in the squash blossoms, *either the infested blossoms must be picked off and destroyed or else the entire vines removed and destroyed as the later-planted ones come into bloom.* Muskmelons may be completely protected by this means if the trapped worms in the squash plants are destroyed regularly. The flavor of the fruits is not affected by growing squash among them, but the seeds from such fruit cannot be used.

Reference.—N. C. Agr. Exp. Sta. Bull. 214, 1911.

Melon Worm[1]

The melon worm is a close relative of the pickle worm and its life cycle and habits are very similar, except that this species feeds much more extensively on the foliage than the pickle worm, rarely enters the vine or leaf petioles, appears a little later, and attacks pumpkins as well as the other cucurbits, but it is rare in watermelons. It is rarely injurious north of the Gulf States, although the adults at least are found from South America to Canada. The adult of the melon worm (Fig. 306) is a beautiful

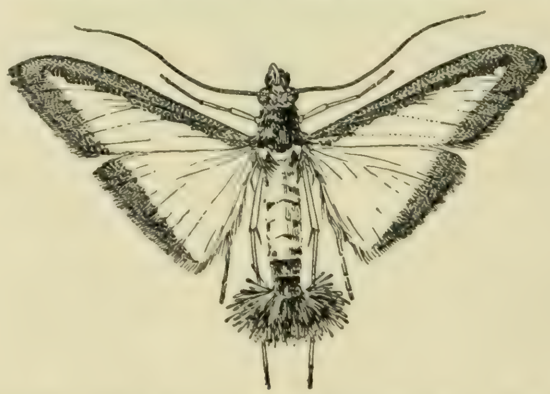


Fig. 306.—Adult of the melon worm, twice natural size. (*From Crosby and Leonard "Manual of Vegetable-garden Insects," copyright,* 1918, *by the Macmillan Company. Reprinted by permission.*)

moth with a wing expanse of about 1 inch. The wings are pearly white, with a narrow dark-brown band about $\frac{1}{16}$ inch wide all around the front and outer margins. The body in front of the wings is dark brown, while the hinder part of the thorax and abdomen are silvery white with a large bushy tuft of darker hairlike scales at the tip of the body. The greenish caterpillar may be distinguished from the pickle worm in all but the smallest and largest stages by having two white, well-separated, slender stripes the full length of the body on the upper side and by lacking the dark spots. They are somewhat more slender than pickle worms, and more active in their movements.

Control Measures.—Since, according to R. I. Smith, the larvæ of this species feed a good deal on the foliage, they can be destroyed by the application of a spray or dust of arsenate of lead, wherever their destructiveness warrants the expense. The application should be made while the worms are still small, and should be directed against the under sides of the leaves. Dusting is best because the cloud of dust will cover the under sides of the low-growing leaves more successfully. In general, the control measures recommended for the pickle worm will also help to control this species.

Reference.—N. C. Agr. Exp. Sta. Bull. 214, 1911.

[1] *Diaphania hyaliniata* Linné, Order Lepidoptera, Family Pyralididæ.

D. INSECTS INJURIOUS TO POTATOES

FIELD KEY FOR THE DETERMINATION OF INSECTS INJURING THE POTATO

A. Insects chewing holes in the leaves:

1. Very convex, nearly hemispherical beetles, about 3/8 inch long, yellow in color, with black spots on the prothorax and five black stripes on each wing cover; and brick-red, humpbacked, soft-bodied larvæ of various sizes up to 3/5 inch in length, with two rows of black spots along each side of the body; eat the leaves and tender shoots. *Colorado potato beetle*, page 472.

2. Elongate, nearly parallel-sided, not very hard, active, long-legged beetles, either black, or grayish, or black with narrow gray or yellow stripes or margins on the wing covers, swarm upon the plants, devouring blossoms and leaves. *Blister beetles*, page 474.

3. Very small, elongate oval, black beetles from 1/16 to 1/8 inch in length rest on the leaves and jump readily when disturbed. Eat small rounded holes into the leaves. Leaves look as though peppered with fine shot. Very delicate, slender, white larvæ, up to 1/5 inch long, with brown heads and six very short legs near the head, sometimes found feeding on roots or tubers. *Flea beetles*, page 437.

B. Insects sucking sap from leaves or stems:

1. Small, very active, greenish, slender, wedge-shaped, jumping bugs, from 1/8 inch down in length, suck sap from under side of leaves, causing tips of leaves to turn brown, followed by the browning and curling of the entire margin, the tissue along the midrib dying last of all. *Apple leafhopper*, page 475.

2. Small, soft-bodied, green, or sometimes pink, aphids, the largest from 1/6 to 1/8 inch long, some winged and others wingless, cluster on under side of leaves and terminal shoots causing them to wilt, curl, and die. Vines become covered with sticky "honeydew." *Potato aphid*, page 478.

C. Insects boring in the stem and leaves:

1. Legless white grubs, about 1/4 inch long, with brown heads, bore up and down the stalks, causing the leaves and stem to wilt and die. Small, dark gray, straight-sided, snout beetles about 1/5 inch long, with three small black spots at the junction of prothorax and wing covers, feed by gouging out slender deep holes in the stems. *Potato stalk borer*, page 480.

2. Caterpillars, up to 1½ inches long, prominently striped with brown and white in front and behind, but with a large, grayish brown, "bruised-looking" area about the middle, mine in the leaves or burrow through the heart of the stems, killing the terminals. Especially troublesome around weedy margins of fields in early summer. Stripes become fainter and disappear when caterpillars are full grown. *Common stalk borer*, page 337.

3. White caterpillars, up to 1/2 inch long, with a pinkish or greenish tinge, and brown at each end, form blotch mines in the leaves or bore through petioles and terminal stems, causing the shoots to wilt and die. *Potato tuber moth*, page 481.

D. Insects attacking the tubers underground:

1. Tubers tunneled with deep, more or less cylindrical burrows, about the diameter of a match, by shining, slick, reddish-brown, tough, six-legged worms up to 1½ inches long by 1/8 inch thick. *Wireworms*, page 432.

2. Tubers gnawed and eaten away in irregular, broad, scabby areas over the surface, by white, curved-bodied grubs with reddish-brown heads and six long slender legs. *White grubs*, page 433.

3. Tubers in low ground or when stored in damp places occasionally attacked by a slender, white, black-headed maggot, only 1/16 inch long when full-grown, that bores

through the flesh, causing superficial wounds that resemble potato scab. *Potato scab gnat, Pnyxia scabiei* Hopk. (see *Proc. Entomol. Soc. Wash.* Vol. 3, p. 152, 1895).

4. White caterpillars up to ½ inch long, with a pinkish or greenish tinge, and brown at both ends, tunnel through tubers in the field or in storage. *Potato tuber moth*, page 481.

5. Yellowish-white, legless maggots, about ¼ inch long, burrowing over the surface and through the tubers of seed potatoes. *Seed-corn maggot*, page 300.

Colorado Potato Beetle[1]

The common yellow and black-striped "potato bug" is perhaps the best known beetle in all America. When first known to man, it occupied the eastern slopes of the Rocky Mountains from Canada to Texas and its food was the weed known as buffalo bur or sand bur.[2] It was described and named by Thomas Say, one of the earliest American entomologist-explorers, in 1824, and for 30 years longer it continued to live as an obscure beetle of no importance to man. The pioneer settlers, pushing westward across the continent, finally brought to this insect a new food, the potato. The insect soon largely deserted the weeds for the cultivated plant and began spreading eastward from potato patch to potato patch, often destroying the entire crop wherever it appeared. It was recorded in Nebraska in 1859, in Illinois in 1864, in Ohio in 1869, and reached the Atlantic coast in 1874. Its average annual spread, was about 85 miles a year. Nothing was known about spraying in those days, and the insect multiplied and spread almost unchecked until about 1865, when it was discovered that Paris green could be used to poison it.

Importance and Type of Injury.—Both the yellow and black-striped, hard-shelled beetles and their brick-red, black-spotted, soft-skinned young or larvæ feed by chewing the leaves and terminal growth of the potato. Unless killed by stomach poisons, they soon devour so much of the vines that the plants die and the development of tubers is prevented or the yield greatly reduced.

Distribution.—Throughout the United States except parts of Florida, Nevada, California, and Canada.

Plants Attacked.—Potato is the favorite food. When this cannot be found, the insect may survive on tomato, eggplant, tobacco, pepper, ground cherry, thorn apple, Jimson weed, henbane, horse nettle, belladonna, petunia, cabbage, thistle, mullein, and perhaps other plants. It is a pest chiefly of potato.

Life History, Appearance, and Habits.—The adult stage goes through the winter buried in the soil to a depth of several inches, seldom more than 8 or 10. This is the only stage that survives the winter. The beetles come out of the ground in spring in time to meet the first shoots

[1] *Leptinotarsa decemlineata* (Say), Order Coleoptera, Family Chrysomelidæ.

[2] *Solanum rostratum.*

of volunteer or early-planted potatoes. These adults (Fig. 307, *a*) are familiar to nearly everyone, and may be recognized by the alternate black and yellow stripes that run lengthwise of the wing covers, five of each color on each wing cover. They are about ⅜ inch long by ¼ inch wide and very convex above. The orange-yellow eggs are deposited on the under side of the leaves, in close-standing groups averaging a couple of dozen each. A number of batches of eggs are matured by each female until an average of about 500 are deposited in the course of 4 or 5 weeks. The overwintering adults then die, and about a week after the eggs were laid, small, humpbacked, reddish, chewing larvæ hatch, and likewise attack the leaves. They grow very fast, passing through four instars, similar except for size. The largest (Fig. 307, *b*) are a little more than ½ inch long, the back arched in almost a semicircle, with a

FIG. 307.—Colorado potato beetle, *Leptinotarsa decemlineata* Say: *a*, adult, *b*, larva or slug, side view; *c*, pupa; about twice natural size. (*From U. S. D. A. Farmers' Bull.* 1349.)

swollen head and two rows of black spots on each side of the body. They usually feed in groups, completely consuming the leaves. These slug-like, reddish larvæ are frequently supposed to be a different kind of potato pest from their parents.

If the full-grown larvæ are watched, however, they will be found to descend into the soil, make a spherical cell and transform to a yellowish, motionless, pupa stage (*c*) which lasts 5 to 10 days. Then the adult beetles appear from the pupæ, crawl up out of the ground and, after feeding for some days, may lay eggs for a second generation. Two generations appear to be the rule, although there may be only one in the North and there is a partial third in the more southern part of their range.

Control Measures.—Both adults and larvæ are easily controlled by thorough spraying or dusting with any good stomach poison, as arsenate of lead, arsenate of calcium, or even Paris green and lime. These treatments should be made at any time that beetles or larvæ appear on the vines. Arsenate of lead at a strength of 2 pounds to 50 gallons of spray, and applied at the rate of 100 gallons per acre for good-sized vines, is a standard spray for these insects. All parts of the vines must be covered with the spray. When potatoes are being sprayed with

Bordeaux mixture for flea beetles, leafhoppers, or potato blights, the arsenical may be added to the Bordeaux when needed to destroy the "bugs," thus saving the expense of a separate application. For small patches of potatoes, arsenate of lead or arsenate of calcium may be dusted lightly over the foliage from an open-meshed bag or sifter can or hand duster.

References.—Iowa Agr. Exp. Sta. Bull. 155, 1915; *U. S. Bur. Entomol. Circ.* 87, 1907; *Jour. Agr. Research*, Vol. 5, pp. 917–925, 1916.

Blister Beetles[1]

Importance and Type of Injury.—Older people often call these "old fashioned potato bugs," because they were much more noticeable on potato before the Colorado potato beetle invaded the central and eastern states. They are slender beetles, about four times as long as wide, rather soft, with the head distinctly set off from the wing covers (Fig. 308), and black, or grayish-colored, or black with narrow yellowish or gray stripes or margins on the wings. Only the adults feed on foliage, but they are very ravenous and may destroy many plants.

Fig. 308.—The black blister beetle, *Epicauta pennsylvanica* De Geer. Line indicates natural size. (*From Bruner.*)

Plants Attacked.—The several species of blister beetles attack potato, tomato, egg plant, sweet potato, bean, pea, soybean, cowpea, melon, pumpkin, onion, spinach, beet, carrot, radish, cabbage, corn, oats, barley, clover, cotton, clematis, aster, chrysanthemum, zinnia, and other crops, and weeds.

Distribution.—Blister beetles will be found in all parts of the United States and Southern Canada.

Life History, Appearance, and Habits.—The life cycles of only a few American species have been worked out. That of the striped blister beetle[2] is briefly as follows: The insect winters as a full-fed, but not fully transformed, larva, known as a pseudopupa (Fig. 309, *g*), in an earthen cell in the soil. It is about ⅗ inch long, yellow, tough-skinned, and with much reduced legs and mouth parts. According to Crosby and Leonard, it may pass through several years in this condition, but usually in the spring it molts, acquiring functional legs and moving about a while before it pupates. The true pupa stage lasts about 2 weeks, and then the adults come out suddenly in great numbers in June and July. They are very restless, active beetles that tend to feed together in swarms. Their bodies contain an oil known as cantharidin, which will blister the tender skin if the beetles are crushed on it (see p. 45). The females lay their eggs in clusters of 100, more or less, in holes that they make in the soil. The eggs are elongate, cylindrical, yellow objects which hatch in 10 days to 3 weeks to very active, strong-jawed little larvæ (*c*) that burrow through the soil until they find an egg mass of a grasshopper. They gnaw into the egg pod and begin eating the eggs. During the next 4 or 5 weeks, the larva molts four times, undergoing a remarkable series of changes in form and appearance known as a *hypermetamorphosis*, during which its legs, mouth parts, and other appendages become progressively smaller and smaller (Fig. 309, *c*, *d*, *f*, *g*), until it reaches the pseudopupa stage, already described, in

[1] *Epicauta vittata* Fabricius, *E. pennsylvanica* De Geer and other species, Order Coleoptera, Family Meloidæ.

[2] *Epicauta vittata* Fabricius.

which it winters. This species apparently has one generation or less a year. Some other species appear to have two generations a year. Several of them are known to feed as larvæ in the egg capsules of grasshoppers. So we have come to believe that the larvæ of blister beetles are very beneficial, although the adults may be very injurious. In Europe, some species feed in the nests of solitary bees, eating the eggs and honey. More work upon the life cycles of our species is much needed.

Control Measures.—Blister beetles are hard to control because they are very active and are repelled by, or resistant to, arsenicals. Dusting with sodium fluosilicate has given good control of certain species of blister beetles. A strong application of this material or of arsenate of calcium or arsenate of lead using 1 ounce to each gallon of water should be made at the first appearance of the beetles. The arsenical may be combined with Bordeaux mixture, which is very repellant to the beetles, and Bordeaux

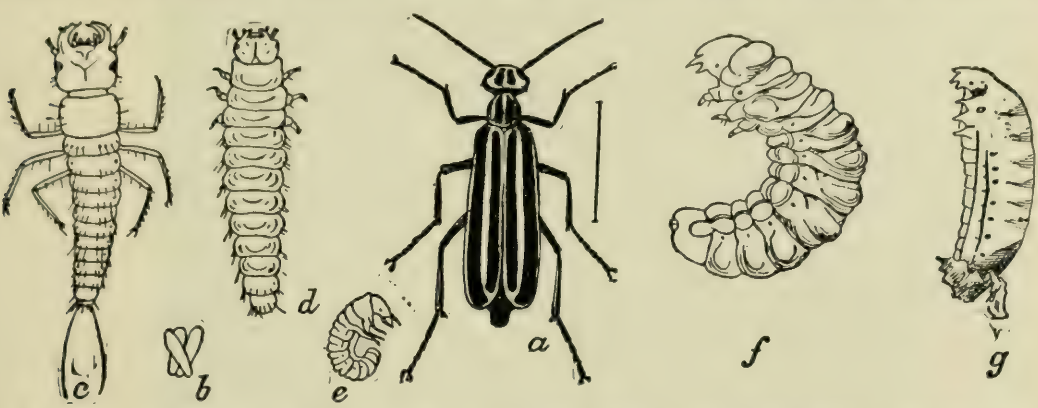


FIG. 309.—Life stages of the striped blister beetle, *Epicauta vittata* Fabricius. *a*, adult; *b*, eggs, *c*, first larval stage (*triungulin*); *d*, second (*caraboid*) stage; *e*, same as *f*, as doubled up in pod; *f*, third (*scarabœoid*) stage; *g*, pseudopupa or *coarctate* larval stage. All but *e* enlarged. (*Reprinted from "Insect Pests of Farm, Garden, and Orchard" by Sanderson & Peairs, published by John Wiley & Sons, Inc., after U. S. D. A.*)

used alone will give fair protection to the vines. Plants that will not stand a heavy application of arsenicals may be protected by knocking the beetles off into pans of kerosene, or if very valuable the plants may be covered with mosquito netting.

References.—*Iowa Agr. Exp. Sta. Bull.* 155, pp. 377–380, 1915; CROSBY and LEONARD, "*Manual of Vegetable-garden Insects,*" pp. 302–312, 1918.

APPLE LEAFHOPPER[1]

Importance and Type of Injury.—In recent years this little, wedge-shaped, green leafhopper, only $\frac{1}{8}$ inch long, has been recognized as the most serious insect enemy of potatoes, at least throughout the North Central States. The insects feed on the under side of the leaves, sucking out the sap and, in some manner not fully explained, cause the trouble known as tipburn or hopper burn (Fig. 310). It appears that only this species of leafhopper produces hopper burn and it causes it on several kinds of plants. The first symptom of this trouble is the appearance of a triangular brown spot at the tip of the leaf. Similar triangles may appear at the end of each lateral veinlet, or the entire margin may roll upwards and turn brown at one time, as though scorched by fire or

[1] *Empoasca fabæ* Harris, Order Homoptera, Family Cicadellidæ.

drought. These brown margins increase in width until only a narrow strip of the leaf along the midrib remains green, the rest shriveled and dead. Older leaves below the growing tips usually burn first but in cases of heavy infestations every leaf rapidly succumbs and the vines die long before the normal development of the tubers has been completed, thus greatly cutting the yield. Many other agencies cause a browning of the leaf area of potatoes but the typical relation of the spots to the veins, just described, is characteristic of this particular trouble. The diagnosis may be confirmed by finding the leafhoppers on the under

Fig. 310.—Work of the apple leafhopper, showing typical hopperburn at left, compared with a normal leaf at right. (*From Parrot.*)

side of the leaf. Hartzell[1] estimates that the number of hoppers to an acre of potatoes may run between five and six millions.

Plants Attacked.—For many years this insect has been known as the apple leafhopper because its most extensive known injury was to apple nursery stock. It also feeds on beans, potatoes, eggplant, tomatoes, rhubarb, soybeans, clover, alfalfa, raspberry, dahlia, box elder, Carolina poplar, curly dock, pigweed, broad-leaf plantain, sumac, and dandelion.

Distribution.—Early varieties of potatoes are generally more damaged than late ones. Irish Cobbler and Green Mountain varieties are somewhat resistant; while Early Triumph, Early Ohio, Rural New Yorker, and Sir Walter Raleigh are more seriously damaged.

Life History, Appearance, and Habits.—The apple leafhoppers winter in the adult condition under leaves, trash, dense grass, weeds, and the like. They are, in this condition, about $\frac{1}{8}$ inch long, by one-fourth as broad, of a general greenish color and somewhat wedge-shaped (Fig. 311).

[1] In *Jour. Econ. Entomol.*, Vol. 14, No. 1, pp. 62–68, February, 1921.

They are broadest at the head end, which is rounded in outline, and taper evenly to the tips of the wings. There are a number of faint white spots on the head and thorax, and one of the characteristic marks of this species is a row of six rounded white spots along the anterior margin of the prothorax, which can be seen with a hand lens. The hind legs are long, and enable the insect to jump a considerable distance.

The females become active in April and feed until June on bush beans, grasses, young apple trees, and curly dock and other weeds. During June a spring flight takes place to early potatoes. The males and unmated females come out of hibernation at this time and join the earlier females on the potato plants. During the next month or 6 weeks, the females lay their eggs, one to five a day, mostly at night, thrusting them into the tissues of stems and midribs of the leaves, where they are practically invisible, being very slender, curved, whitish objects only $\frac{1}{24}$ inch long. The egg stage lasts from 1 to 2 weeks, depending on the temperature. The nymphs that hatch out are similar in shape to the adults, but lack the wings and are very small and pale colored so they are really hard to see on a leaf. They usually complete their growth on the leaf where they hatched, feeding from the underside and increasing in size, greenness, and activity as they shed their skins, and at the fifth molt appearing as adults. They do not jump readily but usually run sidewise over the edge of the leaf to get away. They may complete their growth in from 1 to 4 weeks, varying with the temperature. Nymphs are most abundant on early potatoes in late June and July, but some do not mature until late in August. The earlier adults of the new generation carry on during July a general migration from the dying vines of early potatoes to the fresh ones of late potatoes, mating and producing a second generation of nymphs during August and September, which cause the burning of late potatoes. DeLong reports partial third and fourth generations in Ohio. The first frosts appear to kill any nymphs still present, and the adults, when potato vines die, fly to various plants not killed by the cold, such as curly dock and rhubarb and feed until the death of these plants forces them into hibernation.

Fig. 311.—Adult of the apple leafhopper, *Empoasca fabæ* Harris, greatly enlarged. Line at left indicates natural size. (*From Ill. State Nat. Hist. Sur.*)

Control Measures.—Fortunately Bordeaux mixture, which is the most important potato spray for fungus diseases, is an effective repellent for

leafhoppers, preventing egg laying, and also killing some of the younger hoppers. It should be applied as soon as the plants are 4 to 8 inches high and at 1-week or 10-day intervals as long as the vines can be kept green. This usually requires four or five sprayings. A 4-6-50 home-made Bordeaux is recommended. See page 260 for directions to make Bordeaux. Two years' results in Ohio, with practically no other potato troubles present, gave an average increased yield for the spraying of 31 bushels per acre and a net gain of $30 per acre.[1] Experience in several states indicates that where potatoes are properly sprayed for protection from this leafhopper the yield has been increased on the average about one-third. On the average, the total cost of sufficient sprays to control this insect would be from $8 to $10 per acre. DeLong found oleoresin of pyrethrum extract, 1 to 300 in water, or more dilute with miscible oils, an effective spray on beans. Dusting with commercial copper dusts is nearly as effective as spraying.

References.—*Wis. Agr. Exp. Sta. Bull.* 334, 1921; *U. S. Dept. Agr. Farmers' Bull.* 1125, 1921; *Iowa Agr. Exp. Sta. Circ.* 77, 1922; *Jour. Econ. Entomol.* Vol. 14, pp. 62–68, 1921; and Vol. 21, p. 183, 1928; *Wis. Agr. Exp. Sta. Res. Bull.* 82, 1928.

Potato Aphid[2]

Importance and Type of Injury.—The epidemics of this insect are extremely sporadic. Severe outbreaks (Fig. 312) result in the complete browning and killing of the vines of the potato by curling and distorting the leaves from the top of the plant downward. On tomato, the most noticeable injury is the devitalizing of the blossom clusters so that the blossoms fall and no tomatoes set. Green or pinkish, winged or wingless aphids cluster in shaded places on the leaves, stems, and blossoms. Winged migrants spread from field to field, so that the epidemic may sweep over a district in an alarming manner. Following such an outbreak, the insect may not visit a community in conspicuous numbers again for many years. In all probability the transmission of tomato and potato diseases, such as mosaics, leaf roll, and spindling tuber, by the feeding of these aphids, causes more injury to the plants than sucking the sap.

Plants Attacked.—Potato, tomato, eggplant, pepper, ground cherry, sunflower, pea, bean, apple, turnip, buckwheat, aster, gladiolus, iris, corn, sweet potato, ragweed, lamb's quarters, shepherd's purse, and many other weeds and crops.

Distribution.—Maine to California and Florida to Canada; probably in every state.

Life History, Appearance, and Habits.—The winter eggs (see p. 442) are deposited chiefly on rose, and the aphids may be found regularly on

[1] *Ohio Agr. Exp. Sta. Bull.* 368, June, 1923.

[2] *Illinoia solanifolii* (Ashmead), Order Homoptera, Family Aphididæ.

the succulent parts of rose bushes in the spring. During the first half of July, in Maine, winged aphids develop, that fly to potato, and some of the others crawl to their summer host. A generation may be developed on potato every 2 or 3 weeks, and each unmated female may give birth to 50 or more active nymphs within two weeks time. Thus the vines rapidly become covered with aphids, which blight the stems and wither the leaves. On a single large tomato plant, 24,688 aphids have been counted. By the middle of September, in Maine, and usually by early October, in Ohio, the aphids have all deserted potatoes and dispersed to

FIG. 312.—A field of potatoes killed by the potato aphid. (*From Ohio Agr. Exp. Sta. Bull.* 317.)

other plants, of which the rose is the favorite. Here wingless, egg-laying females develop as the last generation of the season, and, after mating with males that fly over from the summer host plants, the winter eggs are laid on stems and leaves of the rose.

The potato aphid when full-grown is nearly ⅛ inch long, of a clear green or pink, glistening color and with long slender cornicles (see Fig. 63, *B*). The wingless ones tend to drop from the plant when disturbed.

Control Measures.—Nicotine sulphate 1 part to 500 parts of soapy water, thoroughly applied from one to three times, at intervals of 2 or 3 days, will control the severest outbreaks. Nicotine dusts may also be used (see p. 241). Because of the many host plants on which this aphid may develop, clean cultivation in the truck patch is important in preventing outbreaks. If rose bushes are permitted to grow in abundance

near potato fields, they afford a place for an abundance of overwintering eggs.

References.—*Me. Agr. Exp. Sta. Bull.* 242, 1915, and 323, 1925; *Ohio Agr. Exp. Sta. Bull.* 317, 1917.

Potato Stalk Borer[1]

Importance and Type of Injury.—In some sections, this stalk borer is abundant enough in certain years to destroy entire fields of potatoes. Throughout much of its range it is of little importance. Chief injury is due to the larvæ eating out the interior of the stalks, causing the entire plant to wilt and die. The adults eat slender, deep holes in the stems.

Plants Attacked.—Potato, eggplant, and related weeds, such as Jimson weed, horse nettle, and ground cherry. Most injurious to early potatoes.

Distribution.—Over the United States, except the northernmost states.

Life History, Appearance, and Habits.—The insect goes through the winter in or among the old vines in the adult stage. These adults are blackish snout beetles,

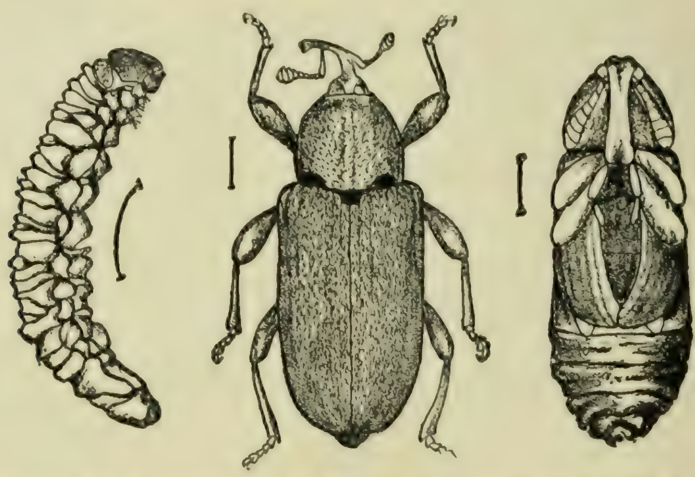


Fig. 313.—Potato stalk borer; larva, adult, and pupa; the lines show natural size. (*Reprinted from "Insect Pests of Farm, Garden and Orchard" by Sanderson and Peairs, published by John Wiley & Sons, Inc., after J. B. Smith.*)

about ⅕ inch long, covered with flattened gray hairs or scales that give them a frosted appearance. There are three distinct black dots at the base of the wing covers (Fig. 313). In late spring they emerge and feed by eating deep holes in the stems of the new plants. The eggs are placed singly in similar cavities in the stem or leaf petioles, and hatch in a week or 10 days. The larvæ eat up and down in the stems, completely hollowing them out for several inches. They are yellowish-white, legless, wrinkled grubs with brownish heads, and range up to about ⅓ inch long (Fig. 313). Before pupating, the larva packs its burrow with excelsior-like scrapings from the stem and chews an exit hole nearly through the stem for the escape of the adult. A week or two later the pupæ transform to adults which may be found in the stalks, from late July on in the northern states. They do not come out of the larval burrows until the following spring unless the stalks are broken open.

Control Measures.—The only practical control is to collect and burn all potato vines in infested fields, as soon as the crop is harvested. As with most potato insects,

[1] *Trichobaris trinotata* (Say), Order Coleoptera, Family Curculionidæ.

the destruction of Jimson weed, horse nettle, and ground cherry will help to keep down their numbers.

References.—*U. S. Dept. Agr. Bur. Entomol. Bull.* 33, 1902; *Kan. Agr. Exp. Sta. Bull.* 82, 1899.

Potato Tuber Moth[1]

Importance and Type of Injury.—The tubers of potatoes in the field and in storage are riddled with slender, dirty-looking, silk-lined burrows of pinkish-white caterpillars (Fig. 314). The caterpillars are from ⅖ inch downward in length, with dark-brown heads. Some of them burrow in

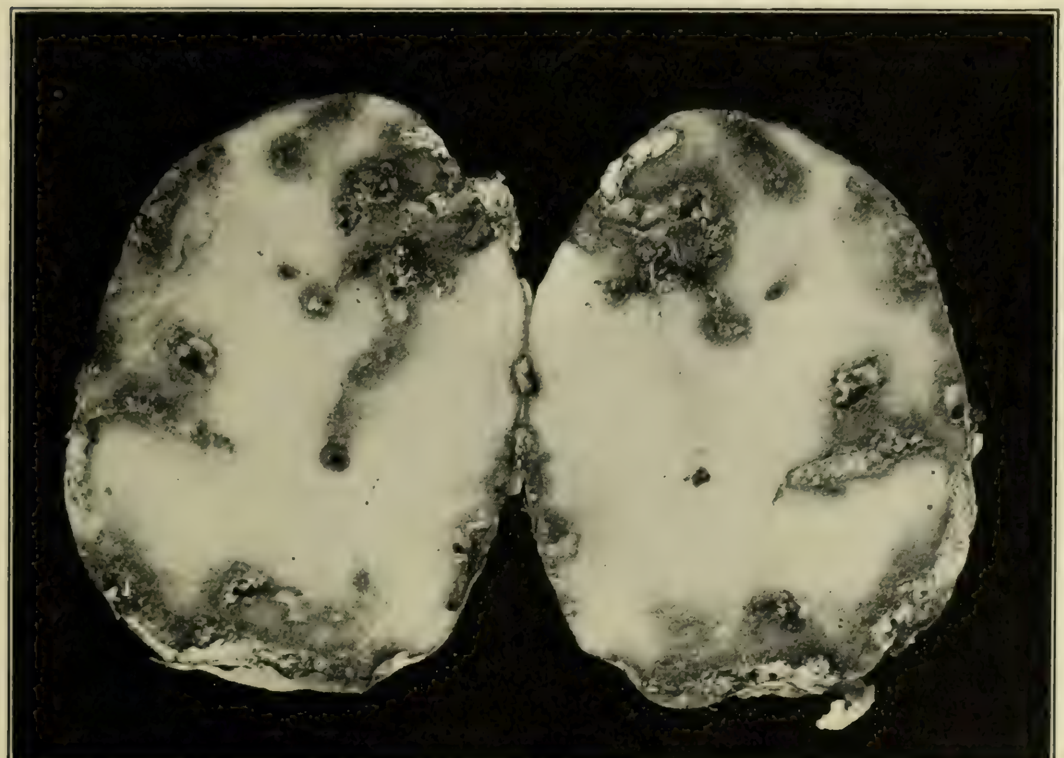


Fig. 314.—Potato cut open to show injury by larvæ of potato tuber moth, *Phthorimœa operculella* Zeller. (*From U. S. D. A. Dept. Bull.* 427.)

the stems and petioles or mine in the leaves. When working on tobacco, the insect is known as the split worm. Their brown blotches, between the upper and lower epidermis of tobacco leaves, make the leaves unfit for wrappers. It is very destructive to potatoes in warm, dry regions where it occurs.

Plants Attacked.—Potato, tobacco, tomato, eggplant, and weeds of the same family.

Distribution.—Southern United States from California to Florida and northward to Washington, Colorado, Virginia, and Maryland.

Life History, Appearance, and Habits.—In storage, the insect may continue to reproduce as long as the potatoes contain enough food to

[1] *Phthorimœa opercullella* Zeller, Order Lepidoptera, Family Gelechiidæ.

mature the larvæ. The moths escape from storehouses in early spring, or winter in sheltered culls out-of-doors. They lay eggs, one in a place, chiefly on the underside of the leaves. Most of the larvæ first produce blotch mines on the leaves but subsequently work down into the stems. They become mature in 2 or 3 weeks, pupate in a grayish, silken, dirt-covered cocoon, about ½ inch in length, entangled in the dead leaves or among trash on the ground, and emerge as adults in a week or 10 days. The adults are very small, narrow-winged moths, ½ inch from tip to tip of the wings, and grayish brown, mottled with darker brown. An entire generation may develop in a month of warm weather, and five or six in a year. The later generations infest the tubers in the field by working down through cracks in the soil to lay eggs upon them, or the larvæ may migrate from the stems to the tubers, or, especially at digging time, the eggs may be laid upon the exposed tubers. The caterpillars at first work just under the skin of the potato but later tunnel through the flesh. Before pupating, they come out of the potatoes and spin up among them or in cracks about the storehouse.

Control Measures.—Potatoes should be deeply hilled so the tubers are not exposed during their development. At digging time, they should not be left exposed to the egg-laying moths during late afternoon or over night. Infested vines should not be piled over the potatoes, for the caterpillars will leave the wilting vines and mine into the tubers. Tubers infested in storage may be saved by fumigating with carbon bisulfide (see p. 258), when the temperature is above 65° F., using 5 pounds to each 1,000 cubic feet of space, for 48 hours. Several fumigations are generally required to give effective control.

References.—*U. S. Dept. Agr. Dept. Bull.* 427, 1917; *Virginia Truck Exp. Sta. Bull.* 61, 1927.

E. INSECTS INJURIOUS TO SWEET POTATOES

FIELD KEY FOR THE IDENTIFICATION OF INSECTS INJURING SWEET POTATOES

A. Insects chewing holes in the leaves or vines:

1. Oval beetles, about ¼ inch long, that look like a drop of molten gold when alive, nearly hemispherical, with the margins of the body extended so as to hide the head and most of the legs; and elongate oval, brown larvæ, up to ⅜ inch long, the margin of their bodies surrounded by about 30 thorny spines, but their backs completely covered with a dirty mass of excrement and shed skins that conceal the body; eat rounded holes in the leaves or devour them completely. *Golden sweet-potato beetle,* page 483

2. Similar to *A* 1, but the beetle is dull yellow in color, with five longitudinal black stripes on the wing covers. The larva with shorter marginal spines and yellowish white in color with a median gray line. A thick tail-like projection, carried at an angle of 45 degrees from the leaf, bears the shed skins, but no excrement. *Striped sweet-potato beetle,* page 483.

3. Similar to *A* 1, but $\frac{5}{16}$ inch long, golden yellow, with three small black spots on each wing cover, arranged in a triangle. The larva straw-yellow with two dark spots behind the head; the marginal spines not very long, black at their tips; the back covered with excrement carried on two long spines and drawn out sideways into long shreds. *Black-legged sweet-potato beetle*, page 483.

4. Beetle similar to the above, golden around the margin, the disc mottled with black and yellow, the black extending out as a slender tooth to each shoulder. The larva is dull green, bluish along the back, and covered with broad branching masses of excrement supported on the anal spines. *Mottled sweet-potato beetle*, page 483.

5. Beetle larger than the above, $\frac{1}{3}$ inch long, yellow to brick red in color, with 15 to 20 small rounded black spots on the forward two-thirds of the back; very convex, and the margins of the body not extended. Larva light yellow, with many small brown spots, $\frac{1}{2}$ inch long; marginal spines long, black-tipped. An irregular mass of excrement held slanting back from the body or vertically over it. *Argus tortoise beetle*, page 484.

6. Very small, black, jumping beetles only $\frac{1}{16}$ inch long, with a bronzy reflection, eat long narrow channels in the leaves, especially on the upper surface, parallel with the veins, during May and early June. *Sweet-potato flea beetle*, page 485.

7. Holes eaten in leaves or leaves skeltonized by bluish-green caterpillars with yellow heads, up to 1 inch in length, which feed inside of folded leaves held together by silk. Injurious in the Gulf States. *Sweet-potato leaf roller, Pilocrocis tripunctata* Fabricius (see *U. S. Dept. Agr. Dept. Bull.* 609, 1917).

8. Leaves and vines eaten by shiny, slender, ant-like snout beetles, $\frac{1}{4}$ inch long, with blue-black head, wing covers, and abdomen, but the middle region of the body and the legs bright red (see also *C* 1, below). *Sweet-potato weevil*, page 486.

9. Plants, or separate leaves, cut off and the heart of the plant eaten out during the night. Plump, greenish-gray or blackish, more or less mottled or striped caterpillars found during the day just below the surface of the soil. *Cutworms*, page 434.

B. Insects sucking sap from the plants:

1. Greenish, motionless, oval, flat nymphs with white waxy spines radiating from their bodies, the largest only $\frac{1}{16}$ inch long, suck sap from the underside of the leaves. The small but conspicuous four-winged white bugs, like tiny moths, fly up when the plants are disturbed. *Sweet-potato whitefly, Bemisia inconspicua* Quaintance (see *Fla. Agr. Exp. Sta. Bull.* 134, 1917).

C. Insects burrowing in the tubers in the field or in storage:

1. Legless, white, fat grubs with pale-brown heads, up to $\frac{1}{3}$ inch long, make winding, excrement-filled tunnels through the tubers, causing them to decay and become bitter and unfit for use. The red-and-blue adult beetles also found in the tunnels (see also *A*, 8, above). *Sweet-potato weevil*, page 486.

Sweet-potato or Tortoise Beetles, or "Gold Bugs"[1]

Importance and Type of Injury.—The foliage of sweet potatoes is very commonly cut full of holes, or entire leaves may be eaten by beautiful oval beetles a little squared at the shoulders, of a golden color, sometimes with black stripes or spots, and about $\frac{1}{4}$ inch long. Similar injury is performed by the spiny, dirt-laden larvæ found on the under side of the leaves. When they attack newly-set plants the injury may be severe.

[1] Order Coleoptera, Family Chrysomelidæ.

Plants Attacked.—These beetles restrict their feeding largely to the plants of a single family, the morning glory family, of which the best known kinds are sweet potato, morning glory, and bindweed.

Distribution.—As a group, the tortoise beetles occur over nearly all of the United States and arable Canada.

Life History, Appearance, and Habits.—The tortoise beetles live through the winter in the beetle stage in dry sheltered places, under bark

Fig. 315.—The argus tortoise beetle. Sweet potato leaf showing *a*, adult; *b*, larva and *c*, pupa. About three times natural size. (*From Jour. Agr. Res., Vol.* 27, *No.* 1.)

or trash. They come out of hibernation rather late, and are found feeding and mating on the plants during May and June. They are turtle-shaped, flat below, and the sides of the prothorax and wings are extended beyond the sides of the body so as to hide the head and much of the legs. The recognition marks of the more important species [1 to 5] are given in the key on pages 482 and 483.

[1] Golden sweet-potato beetle, *Metriona bicolor* (Fabricius).
[2] Striped sweet-potato beetle, *Cassida bivittata* Say.
[3] Black-legged sweet-potato beetle, *Jonthonota nigripes* (Olivier).
[4] Mottled sweet-potato beetle, *Chirida guttata* (Olivier).
[5] Argus tortoise beetle, *Chelymorpha cassidea* (Fabricius).

The females of the striped sweet-potato beetle[1] lay their eggs one in a place, on the leaf stems or veins of the underside of the leaf, covering each white egg with a little daub of black, pitchy material that hides and protects it. The argus tortoise beetle[2] (Fig. 315, *A*) lays her eggs in clusters of 15 to 30, each egg attached to the leaf by a slender pedicel. In about a week or 10 days the eggs hatch, and during June and July the curious larvæ of these beetles (Fig. 315, *B*) are found feeding mostly on the underside of the leaves. They are about 3⁄8 inch long, provided with conspicuous thorny spines all around the margin, two of which at the posterior end are nearly as long as the body. On these long spines, which may be turned up over the back like a squirrel's tail, the larva packs all of its excrement and the skin it sheds at each molt, tying the dirty mass together with silk. The larvæ thus come to look like moving bits of dirt or excrement and are often called "peddlers." When growth is completed, the larvæ fasten themselves to leaves. The somewhat different-looking pupæ (*c*) are exposed by molting the skin, and a week or so later the new adults emerge. They feed a little during August and then go into winter quarters.

Control Measures.—If necessary, the plants in the seed bed, or later in the field, may be sprayed with arsenate of lead, 1 pound to 50 gallons of water.

References.—*N. J. Agr. Exp. Sta. Bull.* 229, 1910; *Jour. Agr. Research*, Vol. 27, No. 1, Jan. 5. 1924.

Fig. 316.—Sweet potato flea beetle, adult, about twenty-four times natural size. (*From Ill. State Nat. Hist. Sur.*)

Sweet-potato Flea Beetle[3]

Importance and Type of Injury.—Long narrow grooves are eaten in the leaves, especially on the upper surface, along the veins, during May and early June by very small, chunky, black, jumping beetles about 1⁄16 inch long, with bronzy reflections and reddish-yellow appendages (Fig. 316). When these channels are numerous the leaf may wilt and turn brown and the plant be killed or badly stunted.

Plants Attacked.—Besides sweet potato, bindweed, and morning glory, corn, wheat, oats, rye, and other grasses, red clover, sugar beet, raspberry and box elder.

Distribution.—General east of the Rocky Mountains.

Life History, Appearance, and Habits.—The small beetles winter under protecting trash in fence rows, the margins of wood lots and other sheltered places. They come out of hibernation and attack the plants about the time they are set out from the seed

[1] *Cassida bivittata* Say.

[2] *Chelymorpha cassidea* (Fabricius.)

[3] *Chætocnema confinis* Crotch, Order Coleoptera, Family Chrysomelidæ.

beds. By the end of June, all have usually left the sweet potato, migrating especially to bindweed, about which they lay their eggs, and then die. Their white larvæ feed on the small roots of bindweed, becoming full-grown and producing the new generation of beetles in late July and August. These beetles make their characteristic feeding channels on bindweed and morning glory in the fall, but rarely attack sweet potato until they come out of hibernation the following spring. They sometimes injure small grains in the fall.

Control Measures.—Plants in the seed bed should be thoroughly sprayed with arsenate of lead, 1 pound to 50 gallons of water. Plants set out late, after the beetles have migrated to weeds, are less liable to injury.

Reference.—N. J. Agr. Exp. Sta. Bull. 229, 1910.

Sweet-potato Weevil[1]

Importance and Type of Injury.—Also known as the sweet-potato root borer, this insect is most injurious to the roots or "tubers" which may be honeycombed by numerous, fat, white grubs, with pale-brown heads, ranging up to 1/3 inch in length. Their tunnels are tortuous and filled with excrement, and, when badly infested, (Fig. 317) the roots are unfit even for stock feed. From 25 to 75 per cent of the crop is often destroyed.

Plants Attacked.—Sweet potato, morning glory, and other plants of the same family.

Distribution.—Confined in this country to the Gulf states. Probably imported from Asia.

Life History, Appearance, and Habits.—Breeding is continuous throughout the winter months, especially in potatoes in storage; and all stages may be found practically every week of the year. The eggs are deposited singly, in small cavities eaten out of the stem, or by preference in the "tuber." They hatch in less than a week and the grubs eat down through the stem or into the potato, feeding for 2 or 3 weeks and causing the potato to develop a bad odor and a bitter taste. About a week more is spent in the pupa stage in a cavity in the tuber and then the beetle eats its way out. The adult is the only stage generally seen. It is a shiny, slender-bodied, ant-like snout beetle, about 1/4 inch long, with blue-black head, wing covers and abdomen, but the middle region of the body (prothorax) and the legs are bright red. The adults feed on the stems and leaves, and soon deposit eggs for another generation. The generations require a month to 6 weeks each and follow each other as long as growing plants or stored potatoes are available.

Control Measures.—Sweet potatoes or slips from infested territory should never be used for planting. Other measures that will prevent serious damage by this weevil are: cleaning up the vines and all infested tubers from the fields promptly after harvest and feeding, burning or burying them deeply; destroying volunteer sweet potatoes and related weeds; putting sweet-potato plantings as far away from those of the pre-

[1] *Cylas formicarius* Fabricius, Order Coleoptera, Family Curculionidæ.

ceding year as possible; spraying the plants with arsenate of lead, 1 pound of powder to 50 gallons of water as soon as weevils appear in the fields.

Fig. 317.—Sweet potato cut open to show injury by sweet potato weevil. Larva in burrow at top; pupa below. Three times natural size. (*From U. S. D. A. Farmers' Bull.* 1020.)

Federal and state quarantines prohibit the movement from the known infested area, of plant material which is likely to carry the insect.

Reference.—U. S. Dept. Agr. Farmers' Bull. 1020, 1919.

F. INSECTS INJURIOUS TO TOMATOES

FIELD KEY FOR THE DETERMINATION OF INSECTS INJURING THE TOMATO

A. Insects cutting off the newly set plants close to the ground:

1. Plants chewed off at night and left lying on the soil. Plump, greasy-looking, green tan, or blackish caterpillars up to 2 inches in length, some of them spotted or striped, found in the soil about plants during the daytime. *Cutworms*, page 434.

B. Insects devouring or eating holes in the foliage:

1. Very small, oval, black, brassy or pale-striped beetles, from $\frac{1}{16}$ to $\frac{1}{8}$ inch long, eat small, round "shot holes" in the leaves, and jump vigorously when disturbed. *Flea beetles*, page 437.

2. Large green caterpillars, up to 4 inches long, with diagonal white bars on the sides and a slender horn at the tip of the body, cling to the vines and strip off the foliage. *Tomato* and *tobacco hornworms*, page 488.

3. Elongate, nearly parallel-sided, not very hard, long-legged beetles, black, grayish, or black with light margins on the wing covers, swarm actively over the plants, devouring leaves and blossoms. *Blister beetles*, page 474.

C. Insects that suck sap from the stems, buds or leaves:

1. Small, soft-bodied, green or pinkish plant lice, the largest $\frac{1}{6}$ inch long, winged or wingless, cluster on underside of leaves and on terminal shoots, sucking their sap and causing them to wilt, curl, and die. Vines become covered with sticky honeydew. *Potato aphid*, page 478.

2. Stems and leaves develop a white fuzzy appearance almost like a white mold, due to the development of hairlike outgrowths under which many minute mites live. *Tomato erinose, Eriophyes cladophthirus* Nalepa (see *Fla. Agr. Exp. Sta. Bull.* 76).

3. Slender, wedge-shaped, greenish or yellowish leafhoppers, under $\frac{1}{8}$ inch long, suck sap of tomatoes and transmit a virus which causes tomato yellows or curly-top; the leaves droop, thicken, become crisp, and later develop a yellow color with purple veins or, in the greenhouse, transparent veinlets. *Beet leafhopper*, page 512.

D. Insects that bore into the fruits:

1. Fruits tunneled, soured and decayed. Plump, striped, light-green or tan to nearly black worms, $1\frac{3}{4}$ inches long when full grown, found partly or wholly buried in the fruits which they are eating, or hiding about the ground in daytime. *Corn earworm* or *tomato fruit worm* and *climbing cutworms*, page 490.

Tomato and Tobacco Hornworms

Importance and Type of Injury.—The best-known tomato insects are the large, green, white-barred worms up to 3 or 4 inches long, with a slender horn projecting from near the rear end (Fig. 318, *b*). They eat the foliage ravenously. They are more seriously injurious to tobacco and are known among tobacco farmers as tobacco worms and "tobacco flies." Some people suppose that they can sting with their horns, but they are entirely unable to hurt a person in any way.

Plants Attacked.—Tomato, tobacco, eggplant, pepper, potato and related weeds.

Distribution.—Both species occur throughout most of the United States, often in the same garden. The southern or tomato hornworm[1] ranges from the northern states southward far into South America. The northern or tobacco hornworm[2] ranges from the southernmost United States into Canada.

Life History, Appearance, and Habits.—The winter stage of the hornworms is very often spaded up or plowed out in the spring. It is a mahogany-brown, hard-shelled, spindle-shaped pupa about 2 inches long, with a slender tongue case projecting from the front and bent

[1] *Protoparce sexta* Johanssen, Order Lepidoptera, Family Sphingidæ.

[2] *Protoparce quinquemaculata* Haworth, Order Lepidoptera, Family Sphingidæ.

around like a pitcher handle (Fig. 318, *c*). From these cases appear in May or June large, swift-flying hawk moths or humming-bird moths, 4 or 5 inches from tip to tip of wings. They fly at dusk and hover about beds of petunias or patches of Jimson weed and other flowers with deep tubular corollas, sipping the nectar with their very long tongues. When not in use, the tongue is coiled up like a watch spring under the head. The moths are grayish or brownish in color, with white and dark mottlings. The adult of the tobacco hornworm[1] may be distinguished from the adult of the other species by the two, clear-cut, narrow, zigzag, dark

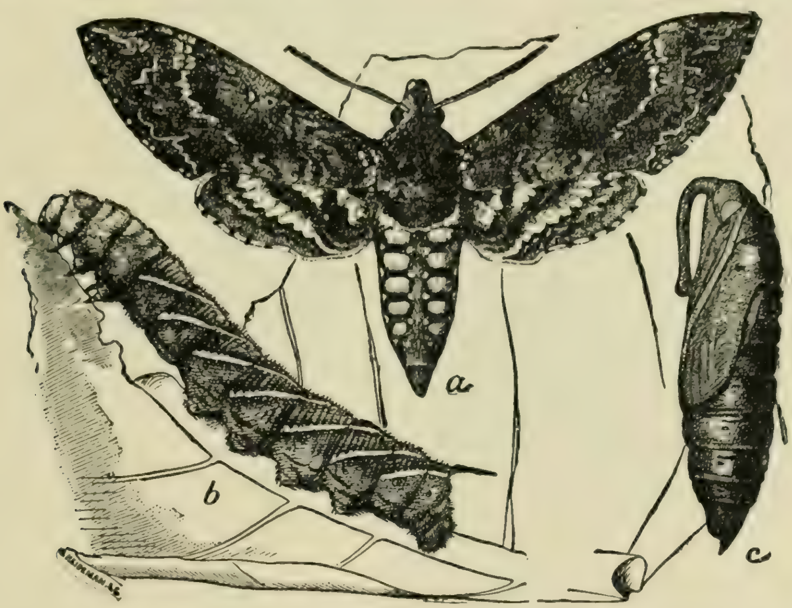


Fig. 318.—Southern or tomato hornworm, *Protoparce sexta* Johanssen, showing adult moth; worm or larva; and pupa; about two-thirds natural size. (*From U. S. D. A.*)

stripes that extend diagonally across each hind wing; these stripes are indefinite and obscured in the tomato hornworm (Fig. 318, *A*). The tobacco hornworm, adult, has five pairs of orange-yellow spots on the abdomen, while the tomato species has six pairs of such spots.

The moths themselves do no injury; but deposit spherical, greenish-yellow eggs, one in a place, on the lower side of the leaves. The small larvæ feed ravenously for about 3 or 4 weeks, during which they shed their skins five times and increase to a length of 3 or 4 inches. The two species are similar, but may easily be distinguished by the diagonal white stripes on each side of the body. In the tobacco-hornworm larvæ, there are eight stripes, each hooking backward from its lower end, forming an L; while in the tomato hornworm (Fig. 318, *b*) there are seven oblique stripes which do not turn backward.

When full-grown, the larvæ, by using their mouth parts and legs, dig into the soil 3 or 4 inches and change to pupæ, which may go through the following winter before they transform to moths. In the southern

[1] *Protoparce quinquemaculata* Haworth, Order Lepidoptera, Family Sphingidæ.

half of their range, however, the pupa stage lasts only about 3 weeks, and at least a part of the adults emerge and produce a second generation late in the season.

Control Measures.—Dusting the plants with powdered arsenate of lead, using 5 pounds per acre on large plants; or spraying with the same material, using $1\frac{1}{2}$ to 2 pounds in 50 gallons of water, and making two applications, one in late June and the other in early August, are recommended for the control of these worms on tobacco. Other arsenicals may be used, but are likely to produce burning. On tomatoes, the dusting should be discontinued at least 10 days before the tomatoes ripen. In small gardens, the worms may often be destroyed by hand more easily than by spraying the plants, locating the well-concealed worms by their droppings. Fall plowing destroys many of the pupæ.

These caterpillars would be much more destructive if it were not for their natural enemies. The most commonly noticed is a braconid wasp.[1] The caterpillars are often found with small white objects covering their backs (Fig. 41), which are generally thought to be eggs. They are, however, cocoons enclosing the pupa stage of the parasite. The eggs of the parasite had been previously thrust through the skin of the hornworm, and the larvæ, after feeding within the worm's body, ate out through the skin and spun the cocoons. The adult wasps later cut out a circular lid and escape from the cocoons to attack other worms. Worms with cocoons on their backs should not be destroyed.

References.—*Tenn. Agr. Exp. Sta. Bull.* 93, 1911; *Ky. Agr. Exp. Sta. Bull.* 225, 1920; *U. S. Dept. Agr. Farmers' Bull.* 1356, 1923.

Tomato Fruit Worms

Importance and Type of Injury.—Among the most serious enemies of the tomato are the plump, greasy, greenish or brownish, striped caterpillars that eat into the fruits from the time they are formed until they are ripe (Fig. 319). The worms are rather restless, and shift from one fruit to another so that a single caterpillar may spoil many fruits without eating the equivalent of a single one. Fifty to eighty per cent of the fruits are sometimes destroyed by these caterpillars. The most serious of these tomato fruit worms is the corn earworm[2] or tobacco bud worm, which has been discussed on page 350. Certain cutworms[3] attack the fruit in the same way (see p. 434). One of the worst infestations by cutworms that the writers have seen was brought about by the owner's cutting a quantity of wild grasses and spreading over the tomato fields as a mulch.

[1] *Apanteles congregatus* (Say), Order Hymenoptera, Family Braconidæ.

[2] *Heliothis obsoleta* Fabricius, Order Lepidoptera, Family Noctuidæ.

[3] Especially the variegated cutworm, *Lycophotia margaritosa saucia* Hübner, Order Lepidoptera, Family Noctuidæ.

Control Measures.—Tomatoes can be protected from injury by these fruit worms by spraying the vines with arsenate of lead, 1 to 2 pounds to 50 gallons of Bordeaux mixture, or water, about the time the earliest fruits are the size of small marbles and again in 10 days. Dusting with arsenate of lead or calcium arsenate at the rate of 5 to 8 pounds per acre, applied at the times recommended for spraying, is very effective.

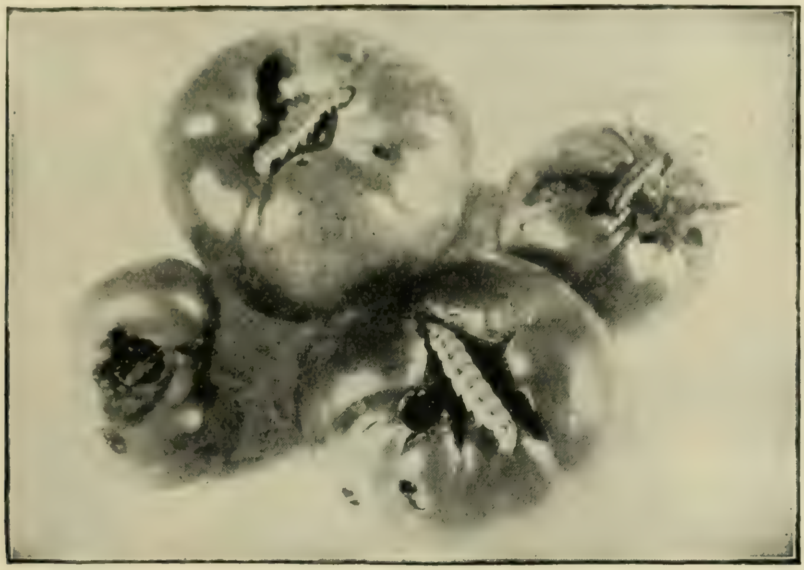


Fig. 319.—Tomatoes with larvæ of the tomato fruit worm feeding in them, about half natural size. (*From Tenn. Agr. Exp. Sta. Bull.* 133.)

The infested fruits should be picked and destroyed by burning or burying a foot or more deep.

Reference.—Tenn. Agr. Exp. Sta. Bull. 133, 1925.

G. INSECTS INJURIOUS TO ONIONS

There are two very serious pests of the onion widely distributed in America: the onion maggot, which feeds in the bulbs; and the onion thrips, a very small, slender bug that draws the sap from the leaves.

Onion Maggot[1]

Importance and Type of Injury.—Small white maggots up to $\frac{1}{3}$ inch in length (Fig. 320, *d*) bore through the underground stem and into the bulbs, causing the plants to become flabby and turn yellow. They mine out the small bulbs completely, leaving only the outer sheath and causing a thin stand that is often blamed to poor seed. Larger bulbs are attacked, often by several maggots that eat out cavities which if not completely destructive to the bulbs, cause subsequent rotting in storage.

Plants Attacked.—This insect is of no importance to any crop except the onion, rarely, if ever, attacking other plants.

[1] *Hylemyia antiqua* Meigen, Order Diptera, Family Anthomyiidæ.

Distribution. Like its close relative, the cabbage maggot, the onion maggot is a pest in the northern part of the United States and in Canada, rarely injurious in the South.

Life History, Appearance, and Habits.—The insect winters mostly as larvæ or pupæ in chestnut-brown puparia (*h*) which resemble grains of wheat, often buried several inches in the soil. They are frequently found very abundant in piles of cull onions. Some adults may survive under the protection of sheds and trash. Those in puparia transform to adults and emerge from the soil over a period of several months in late spring. The adults are slender, grayish-bodied, large-winged, rather bristly flies, only about ¼ inch long (*a*, *b*). The females lay elongate white eggs about the base of the plant or in cracks in the soil.

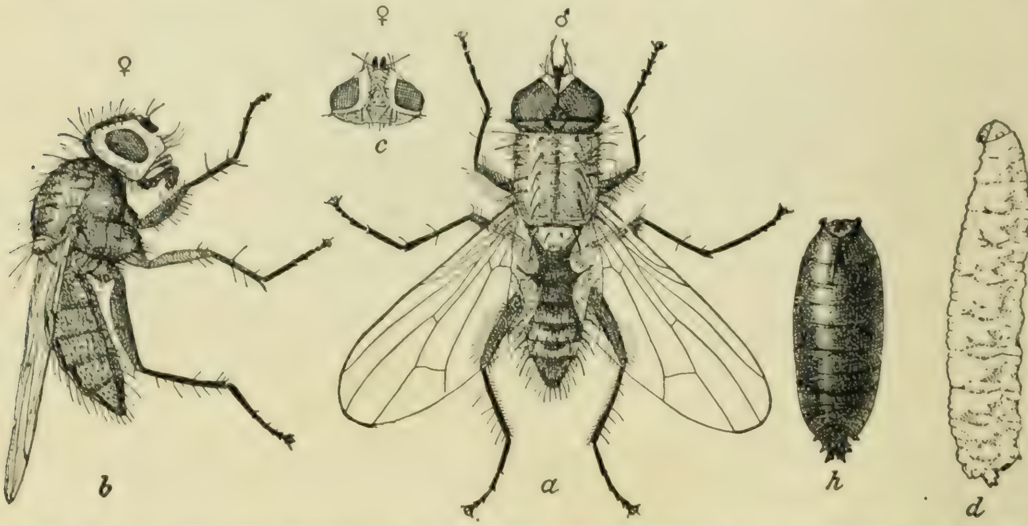


Fig. 320.—The onion maggot, *a*, adult male from above; *b*, adult female from the side; *c*, head of female; *d*, larva or maggot; *h*, puparium; about five times natural size. (*From Ill. State Nat. Hist. Sur.*)

The eggs hatch in from 2 to 7 days, varying with temperature-humidity. The maggots crawl down the plant, mostly behind the leaf sheathes, and enter the bulbs, consuming and spoiling them as stated above. They feed for 2 or 3 weeks. When full-grown, they are about ⅓ inch long, and can be distinguished from the closely related cabbage maggot by the middle lower pair of tubercles at the rear end, which are single- and not double-pointed as in the cabbage maggot. Pupation occurs in the soil about the plant and after 2 or 3 weeks the adults emerge and lay eggs for another generation. A third generation often attacks the onions shortly before harvest, causing them to rot very badly.

Control Measures.—Experimental work conducted in Illinois has developed a very effective control for the onion maggot, by spraying with Bordeaux-oil emulsion. This is made from a 4-6-50 Bordeaux mixture (see p. 260) by mixing with it 1½ gallons of lubricating-oil stock emulsion (see p. 250) to 48½ gallons of the Bordeaux. Five applications

of the spray at weekly intervals, the first when the plants are an inch high, will give practically 100 per cent control. Applications can be made by hand sprayers, or, in large fields, by sprayers attached to tractor cultivators.

The first-generation adults can be attracted to rows of cull onions, planted around the margins of the field and at intervals through the field. These come up earlier and grow faster than the seeded onions and are attractive to the egg-laying flies, thus giving partial protection to the main crop. The maggots in the culls must later be destroyed by spraying with oils, using about 1 gallon to 25 feet of row.

References.—*Jour. Econ. Entomol.* Vol. 18, p. 111, 1925; Vol. 11, p. 82, 1918; *Penn. Agr. Exp. Sta. Bull.* 171, 1922; *Ill. Agr. Exp. Sta. Circ.* 297,1928.

Onion Thrips[1]

Importance and Type of Injury.—The onion thrips is a very minute insect that sucks out the sap of the leaves and stem, causing the appearance of whitish blotches and dashes on the leaves. As the attack increases in severity, the tips of the leaves first become blasted and distorted and later whole plants may wither, brown, and fall over on

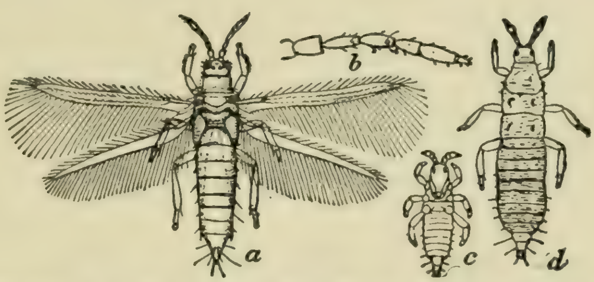


Fig. 321.—Onion thrips. *a*, adult, female; *b*, antenna of same; *c*, small nymph; *d*, full-grown nymph. About twenty-five times natural size. (*From Ill. State Nat. Hist. Sur.*)

the ground. The bulbs become distorted and remain undersized. Entire fields are often destroyed by this pest, especially in dry seasons.

Plants Attacked.—Nearly all garden plants, many weeds, and some field crops. Seriously injurious to onion, cauliflower, cabbage, bean, cucumber, squash, melon, tomato, turnip, beet, sweet clover, and other plants.

Distribution.—In all onion-growing sections of the United States and Canada.

Life History, Appearance, and Habits.—The adults and nymphs both winter on plants or rubbish in the fields or about weedy margins. They are slender, yellow, active bugs, pointed at both ends, the largest of them only $\frac{1}{25}$ inch long (Fig. 321). The males are wingless and very scarce—the females regularly reproducing without mating. The females

[1] *Thrips tabaci* Lindeman, Order Thysanoptera, Family Thripidæ.

have four extremely slender wings which could hardly serve for flight except for the fringe of very long hairs on their hinder margins. The feet also are remarkable in these insects, the tarsus ending in a small bladder, without claws. These bugs squirm in between the leaves and feed, mostly out of reach of insecticides. They rasp and tear the surface of the leaf with their stabber-like mouth parts (see Fig. 69) and swallow the sap, together with bits of leaf tissue. White bean-shaped eggs are thrust into the leaves or stems nearly full length and hatch in 5 to 10 days. The nymphs are very similar to the adults, but paler in color. They become full-grown in from 15 to 30 days, passing through four stages, two of which are passed in the soil and without taking food. After the fourth molt, the adult females return to the plants and soon lay eggs for another generation. Eggs, nymphs, and adults are found together throughout the summer. It is thought that there are usually five or six generations a year.

Control Measures.—No satisfactory, practical remedy has been discovered. Spraying with nicotine sulphate 1 part to 400 or 500 parts of soapy water, using good pressure, holding the nozzle close to the plants, and using enough spray to wet them thoroughly, will destroy many of the thrips. Nicotine sulphate, 1 pint, and 4 pounds of soap should be dissolved in each 50 gallons of spray. After the crop is harvested, the tops should be raked together and burned. The margins of fields should be burned over where practicable to destroy the weeds on which the thrips develop.

Reference.—U. S. Dept. Agr. Farmers' Bull. 1007, 1919.

II. INSECTS INJURIOUS TO CABBAGE AND RELATED VEGETABLES

FIELD KEY FOR THE DETERMINATION OF INSECTS INJURING CRUCIFERÆ

A. Insects that eat holes in the leaves and into the heads:

1. Velvety, green caterpillars with a very slender orange stripe down the middle of the back; of all sizes up to 1¼ inches long, and with eight pairs of legs and prolegs, rag the leaves and eat their way beneath the outer leaves, leaving accumulations of dirty pellets in the leaf axils. White butterflies, nearly 2 inches from tip to tip of the wings, each of which has a few black spots on it, are usually found about the patch. *Imported cabbage worm*, page 495.

2. Caterpillars of similar size and habits to *A* 1, but more striped, the body smooth, and with only six pairs of legs and prolegs, loop over the plants, humping the back high at each "step." Eggs laid at night by somber-brown moths with a silvery spot at the middle of each front wing. *Cabbage looper*, page 498.

3. Small, pale-green caterpillars, not over ⅓ inch long, eat small rounded holes in the leaves from the under side. Wriggle actively when disturbed. *Diamond-back moth*, page 500.

4. Young plants showing many small holes with yellow margins made by the feeding of very small, jumping, black beetles with a crooked yellow stripe on each wing cover. *Cabbage flea beetle*, page 437.

B. Insects that suck the sap from leaves and stems:

1. Showy, red- and black-spotted, stinking bugs, flat and shield-shaped, up to $\frac{3}{8}$ inch long, cause the plants to wilt and die. Not injurious north of fortieth parallel. *Harlequin bug*, page 501.

2. Very small, whitish-green bugs or aphids rest in groups, or great soggy patches, in the heart of the plant or on the under surface of leaves, causing leaves to cup and curl, wilt, and turn yellow. *Cabbage and turnip aphids*, page 503.

C. Insects that eat out the interior of the leaf, forming blotches, but not holes through the leaf:

1. Winding white trails or broad whitish spots appear on leaves, made by small white maggots feeding between the two surfaces of the leaf. *Leaf miners*, page 505.

D. Insects that attack the roots:

1. Plants become stunted and frequently wilt down suddenly during the day and die without apparent external cause. Roots scarred and tunneled by white maggots up to $\frac{1}{3}$ inch long, without legs or distinct head. *Cabbage maggot*, page 505.

IMPORTED CABBAGE WORM[1]

Importance and Type of Injury.—The first-formed, outer leaves of cabbage, cauliflower, and related plants, unless sprayed or dusted, are usually riddled with large holes of irregular shape and size, and the outer layers of the cabbage heads are eaten into by velvety-green worms of all sizes up to $1\frac{1}{4}$ inches long (Fig. 322). If the leaves are parted, masses of greenish to brown pellets (the excrement of the worms) are found caught in the angles of the leaves. So much of the leaf tissue is generally devoured by these worms that the growth of the plants is seriously interfered with (see Fig. 1), the heads of cabbage and cauliflower are stunted or do not form at all, and other leafy vegetables are rendered unfit for consumption.

Plants Attacked.—All the vegetables of the cabbage or mustard family are attacked by these worms—cabbage, cauliflower, kale, collards, kohlrabi, Brussels sprouts, mustard, radish, turnip, horse-radish, and many related weeds. The worms also feed on nasturtium, sweet alyssum, mignonette, and lettuce. The butterflies feed on the nectar in the flowers of cruciferous plants and many other blossoms, but do no damage.

Distribution.—This very common pest was unknown in the new world previous to 1860, when the butterflies were first taken at Quebec, Canada. Within 20 years it had spread over all of the United States east of the Mississippi River. It now occurs as a pest throughout the United States and most of Canada.

Life History, Appearance, and Habits.—Neither the greenish worms nor their well-known, white butterfly parents persist through the winter; but only the pupa stage. This is a naked, grayish, greenish, or tan-colored chrysalid with some sharp, angular projections over its back and in front. It is suspended from some part of the plant or on a building or other object near the cabbage patch. The tail end of the pupa is fastened

[1] *Pieris rapæ* Linné, Order Lepidoptera, Family Pieridæ.

FIG. 322.—Imported cabbage worms, *Pieris rapæ* Linné; and their injury to cabbage leaf. Natural size. (*From Conn. Agr. Exp. Sta. Bull.* 190.)

with a button of silk and kept from hanging head downward by a single loop of silk that encircles the body near the middle, like a girdle (compare Fig. 259, *C*). Early in spring the familiar white butterflies (Fig. 323), with three or four black spots on the wings, split out of the chrysalids and fly about the gardens, alighting frequently to glue an egg to the underside of a leaf of cabbage or related plant. In all, several hundred eggs are laid by a female. They are just big enough to be seen, are shaped like a bullet, are deep yellow in color, and have ridges running both lengthwise and crosswise. Each egg gives rise in about a week to a very small greenish caterpillar which feeds voraciously on the leaves and reaches a length of an inch or a little more in about 2 weeks. These caterpillars (Fig. 322) are an intense leaf green, except for a very slender orange stripe down the middle of the back, and another, broken, stripe along each side of the body, which is formed by a pair of elongate yellowish spots near each

FIG. 323.—Adult male of the imported cabbage worm, natural size. (*From Ill. State Nat. Hist. Sur.*)

spiracle. The worm has a velvety appearance, due to numerous, close-set, short, white and black hairs that form a kind of white bloom over the body. The crawling of these caterpillars is slow and even, the body being supported by three pairs of slender legs and five pairs of fleshy prolegs. When full-grown they frequently crawl some distance away, fasten their tails with silk to some support, spin a silken girdle about the middle of the body and change to the pupa stage. In summer this stage lasts 1 to 2 weeks and other generations succeed until from three to six are completed.

Control Measures.—The imported cabbage worm is easily controlled by arsenicals, the only difficulty being to make the spray adhere to the very waxy leaves. For this purpose a spreader or sticker should be added. An effective spray is made by dissolving 3 pounds of laundry or fish-oil soap, by boiling, in several gallons of water. Add this to enough water to make 50 gallons, and stir into it 1½ to 2 pounds of powdered arsenate of lead or calcium arsenate. For small quantities, use from ½ to 1 ounce of the arsenical and an inch cube of soap to make each gallon of spray.

Arsenate or lead or calcium arsenate, 1 part, to 3 parts of lime, sulfur, or other carrier, applied as a dust so as to reach both surfaces of the leaves, is effective. No hesitancy should be felt about applying these poisons to cabbage, because the head grows from within, and the outer leaves, which

receive the poison, are always discarded. Careful tests have shown that it would be necessary for a person to eat several dozen heads of cabbage sprayed or dusted in the usual way, at one time, to get enough poison to be harmful. The first spraying or dusting should be given shortly after the plants are set, or the plants should be dipped in the spray mixture as they are set out. In the case of collards, kale, mustard, and other plants of which the free leaves are eaten as greens, or on the heads of cauliflower, spraying and dusting should be discontinued 4 weeks before the crop is gathered. The old stalks should be destroyed and the field plowed soon after the crop is harvested. Weeds such as wild mustard, pepper grass, and shepherd's purse, on which the first generation of worms develop, should be destroyed.

A number of natural enemies prey on these caterpillars and in certain seasons and sections reduce them to a point of no importance. One of these is a small wasp[1] that was purposely brought to America in 1883 from England, and has since spread widely over the country. It lays its eggs in the bodies of the caterpillars, and its young, feeding internally, devour the worm so that it dies. The larvæ of the wasp then spin their small yellowish cocoons, about as big as grains of wheat, in masses on the leaves, often in contact with the cabbage worm on which they fed. A still smaller wasp[2] attacks the worms in a similar way but its young remain inside the worms until the little wasps pupate and then the adult parasites eat out of the dead cabbage worm chrysalids. More than 3.000 of these parasites have been reared from a single cabbage worm.

References.—U. S. Dept. Agr. Farmers' Bull. 766, 1916; *Wis. Agr. Exp. Sta. Research Bull.* 45, 1919.

Cabbage Looper[3]

Importance and Type of Injury.—This species attacks the plant in the same manner as the imported cabbage worm, and the two species are commonly found on the same plant. In certain seasons or sections this species is more destructive than the imported cabbage worm.

Plants Attacked.—In addition to all of the plants of the cabbage family, this species also attacks lettuce, beet, pea, celery, parsley, potato, tomato, carnation, nasturtium, and mignonette.

Distribution.—Throughout the United States, from Canada into Mexico; a native species.

Life History, Appearance, and Habits.—The cabbage looper winters as a greenish to brownish pupa, nearly ¾ inch long, wrapped in a delicate cocoon of white tangled threads attached by one side usually to a leaf of the plant on which the larva fed. The cocoon is so thin that the outline

[1] *Apanteles glomeratus* Linné, Order Hymenoptera, Family Braconidæ.

[2] *Pteromalus puparum* Linné, Order Hymenoptera, Family Chalcididæ.

[3] *Autographa brassicæ* Riley, Order Lepidoptera, Family Noctuidæ.

of the pupa can be seen inside. These pupæ transform in the spring to moths of a general grayish-brown color, about an inch long, with a wing spread of nearly 1½ inches (Fig. 324). The mottled, brownish front wings have a small silvery spot near the middle, somewhat resembling the figure 8; the hind wings are paler brown to bronze. They are nocturnal and much less conspicuous about the fields than the cabbage butterflies, but nevertheless manage to lay many small, round, greenish-white eggs singly on the upper surface of the leaves.

Fig. 324.—Moth of the cabbage looper. One and one-third times natural size. (*From Crosby and Leonard "Manual of Vegetable-garden Insects," copyright,* 1918, *by the Macmillan Company, reprinted by permission.*)

All injury is by the greenish larvæ (Fig. 325) which are similar in size and habits to the imported cabbage worms. The body tapers to the head. There is a thin but conspicuous white line along each side of the body just above the spiracles and two others near the middle line of the back. The larva has three pairs of slender legs near the head and three pairs of thicker, club-shaped prolegs behind the middle. The median half of the body is without legs, and this region is generally humped up when the

Fig. 325.—Full-grown cabbage looper. About one and a half times natural size. (*From Crosby and Leonard "Manual of Vegetable-garden Insects," copyright,* 1918, *by the Macmillan Company, reprinted by permission.*)

insect rests or moves. From this looping habit the common name is derived. Two to four weeks of feeding bring the small looper to full size. It then spins a cocoon similar to that in which the winter is passed, and, in the summer months, appears as an adult again within 2 weeks. There may be three, four, or more generations in a year, the number of worms usually increasing with each generation.

Control Measures.—The same measures are recommended as for the imported cabbage worm, but very thorough dusting or spraying must be done, because the worms crawl very actively and will migrate to parts of a plant that have not been covered by the poison. The looper caterpillars are often almost completely destroyed, usually late in the season, by a wilt disease which causes their bodies to rot.

Reference.—U. S. Dept. Agr. Bur. Entomol. Bull. 33, 1902.

Diamond-back Moth[1]

Importance and Type of Injury.—This is one of the minor cabbage worms, seldom devouring more than a small percentage of the leaves. The very small caterpillars

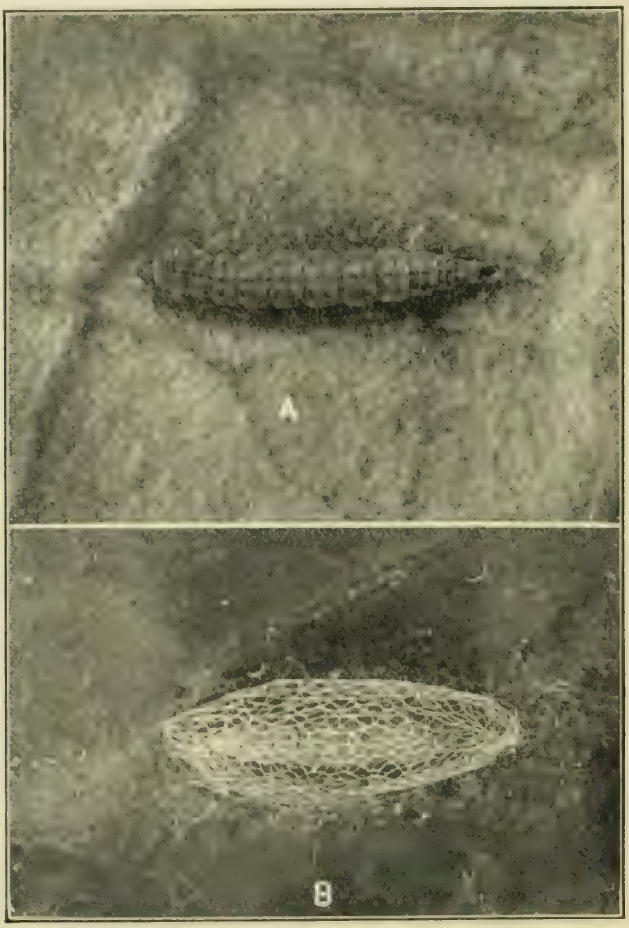


Fig. 326.—Diamond-back moth: larva and silken cocoon. Four times natural size. (*From Mont. Agr. Exp. Sta. Circ.* 28.)

work on the underside of the leaves, eating many small holes, giving a shot-hole effect all over the leaves. In dry seasons they sometimes become abundant enough to cause appreciable injury to young cabbage. On the vegetables of which the outer leaves are eaten and on greenhouse plants they are more serious.

Plants Attacked.—In addition to practically all of the Cruciferæ, the diamond-back moth attacks some ornamental and greenhouse plants such as sweet alyssum, stock, candytuft, and wallflower.

[1] *Plutella maculipennis* Curtis, Order Lepidoptera, Family Plutellidæ.

Distribution.—Introduced into the United States from Europe some time before the middle of the nineteenth century, it now occurs wherever its host plants are grown.

Life History, Appearance, and Habits.—According to Crosby and Leonard, the small grayish moths winter over hidden away under the remnants of the cabbage crop left in the field. They are about ⅓ inch long, the folded wings flaring outward and upward toward their tips, and, in the male, forming a row of three diamond-shaped yellow spots where they meet down the middle of the back. The hind wings have a fringe of long hairs. The minute yellowish-white eggs are glued to the leaves, one, two, or three in a place, and in a few days the very small greenish larvæ are at work on the underside of the leaves. They become full-grown in from 10 days to a month. They rarely exceed ⅓ inch in length, are pale-yellowish-green in color with fine scattered erect black hairs over the body (Fig. 326, *A*), and can be distinguished from small cabbage worms of other kinds by their nervous habit of wriggling actively when disturbed. The cocoon (*B*) within which the full-grown caterpillar changes to the moth, is a beautiful gauzy sack ½ inch long, but so thin and loosely spun that it hardly conceals the pupa. It is usually fastened to the underside of a leaf. The little moth emerges from it within a week or two and promptly starts another generation, of which there may be from two to six or more a year in temperate regions.

Control Measures.—The same as for the imported cabbage worm.

Reference.—Crosby and Leonard, "Manual of Vegetable-garden Insects," 1918.

Other Cabbage Worms

There are several other kinds of caterpillars that often feed on cabbage and related plants and some of them may be locally more abundant than the ones described above. The potherb butterfly[1] and the southern cabbage butterfly[2] are very closely related to the imported cabbage worm; while the cross-striped cabbage worm[3] has numerous black transverse bands across the body and is the young of a small yellowish-brown moth. The cabbage webworm[4] and the purple-backed cabbage worm[5] usually feed beneath a protecting silken web or burrow into the leaves. All of these worms may be controlled by the same methods given for the imported cabbage worm, but for the last two named the applications must be made early, before the young worms gain protection under their webs or in their tunnels.

Reference.—Crossby and Leonard, "Manual of Vegetable-garden Insects," 1918.

Harlequin Bug[6]

Importance and Type of Injury.—The harlequin bug, "fire bug," or "calico back," is to cabbage and related plants in the South what the squash bug is to squashes. It sucks the sap of the plants, taking its food entirely from beneath the surface, sapping them so that they wilt, brown, and die. The gaudy, red-and-black-spotted, stinking bugs (Fig. 327), about ⅜ inch long, flat and shield shaped, and the smaller, similar-looking nymphs have a very characteristic pattern. They may be found in all

[1] *Pieris oleracea* Harris, Order Lepidoptera, Family Pieridæ.

[2] *Pieris protodice* Boisduval and Leconte, Order Lepidoptera, Family Pieridæ.

[3] *Evergestis rimosalis* Guenee, Order Lepidoptera, Family Pyralididæ.

[4] *Hellula undalis* Fabricius, Order Lepidoptera, Family Pyralididæ.

[5] *Evergestis straminalis* Hübner, Order Lepidoptera, Family Pyralididæ.

[6] *Murgantia histrionica* Hahn, Order Hemiptera, Family Pentatomidæ.

stages of development from early spring to winter, and dozens to the plant in severe cases.

Plants Attacked.—Cabbage, cauliflower, collards, mustard, horse-radish, Brussels sprouts, turnip, kohlrabi, radish, and in the absence of these favorite foods, tomato, potato, eggplant, okra, bean, asparagus, beet, and many other garden crops, weeds, fruit trees, and field crops.

Distribution.—This is a southern insect ranging from the Atlantic to the Pacific, and rarely if ever injurious north of about the fortieth parallel. It first spread over the South from Mexico, shortly after the

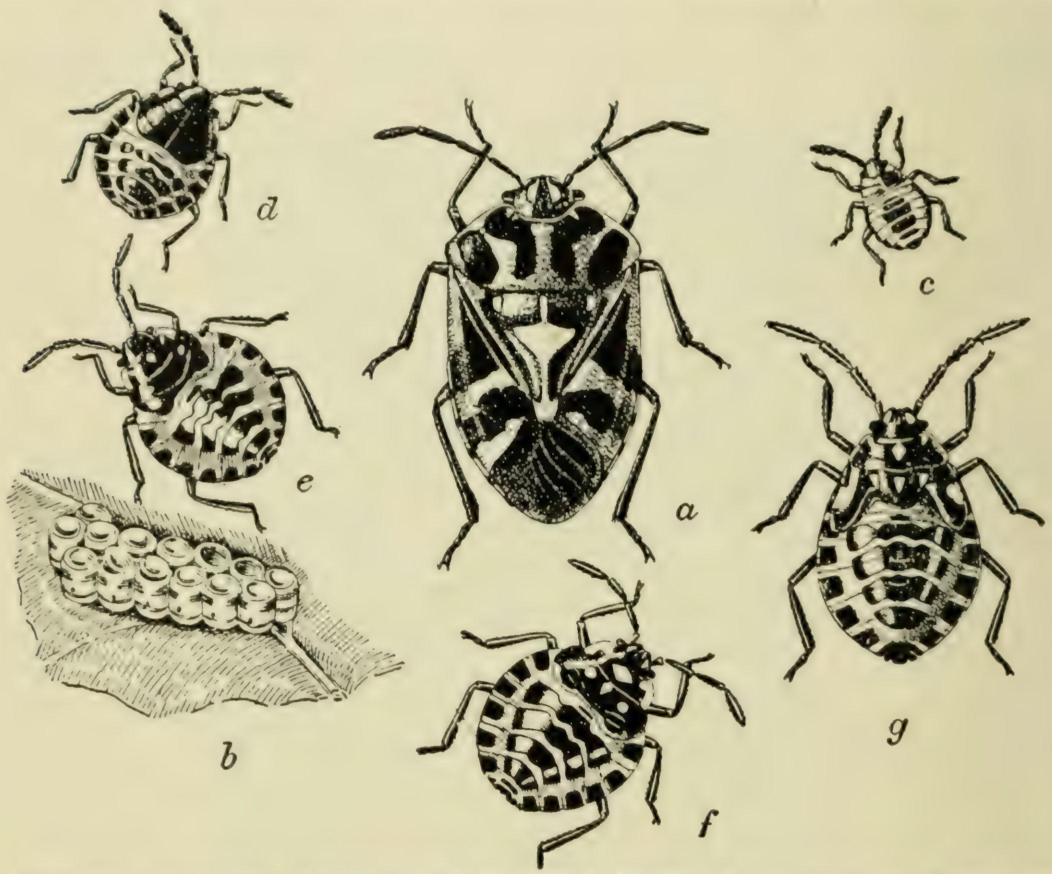


Fig. 327.—Harlequin cabbage bug, *Murgantia histrionica* Hahn: *a*, adult; *b*, egg mass; *c*, first stage nymph; *d*, second stage nymph; *e*, third stage nymph; *f*, fourth stage nymph; *g*, fifth stage nymph—all enlarged about three times. (*From U. S. D. A. Farmers' Bull.* 1061.)

Civil War, and it was believed by many that it was brought in by the Yankee troops.

Life History, Appearance, and Habits.—Throughout most of its range the insect continues to feed and breed during the entire year. Farther north the approach of winter drives the bugs into the shelter of recumbent cabbage stalks, bunches of grass, and other rubbish, and only the adults survive severe winter weather. The first warm days of spring tempt them out of hiding and they begin feeding on weeds, being ready to lay eggs by the time the earliest garden plants are set out. The eggs are laid

mostly on the underside of the leaves. They are like tiny white kegs standing on end in double rows, about a dozen glued together, each "keg" bound with two broad black hoops and with "round black spots set in the proper place for bungholes" (Fig. 327, *b*). The eggs hatch in from 4 to 29 days, the time varying with the temperature, and the very young bugs begin the business of destroying the plants. They feed and grow for 4 to 9 weeks, passing through five distinct stages before they are capable of mating and laying eggs for a second generation. Three generations, and a partial fourth, may succeed each other before cold weather puts a stop to their rapid increase.

Control Measures.—Much time and quantities of arsenicals are wasted every year by persons who do not understand the way in which the harlequin bugs feed, and who try to kill them with applications of Paris green and other stomach poisons. No satisfactory spray or dust for this pest has been discovered. Strong contact sprays and dusts will kill many of them but not enough to constitute a satisfactory control. The most important control is the destruction of the adults in the fall and in the spring as they come out of hibernation and before they have begun egg laying. Hand destruction may be facilitated by the use of trap crops of mustard, kale, turnip, or radish, planted very early in spring or late in fall after the main crop is harvested. When the bugs have concentrated on these small patches, they should be killed by spraying with kerosene, or by covering the trap crop with straw and burning. Trap crops should never be used unless they can be given careful attention to destroy the bugs attracted to them. Weeds such as wild mustard, Amaranthus and others of the mustard family should be kept down. After the bugs have been reduced by the diligent use of the above methods, the stragglers that remain must be cleaned up by hand picking early in the day and destroying the bugs and their egg masses wherever found.

Reference.—U. S. Dept. Agr. Farmers' Bull. 1061, 1920.

CABBAGE[1] AND TURNIP[2] APHIDS

Importance and Type of Injury.—These two plant lice, while easily distinguished by specialists, are very similar in general appearance, and, indeed, were not recognized as separate species until 1914. The nature of attack is similar, and they may be considered together. Plants in seed beds and at all subsequent stages of their growth are frequently covered with dense clusters of whitish green plant lice about the size of the smallest bird-shot, which suck the sap from the leaf (Fig. 328). The affected leaves curl and crinkle or form cups, completely lined with the aphids, and, in severe infestations, wilt and die. The plants, if not killed, are dwarfed, grow slowly, and form small light heads not suitable for market-

[1] *Brevicoryne brassicæ* Linné, Order Homoptera, Family Aphididæ.

[2] *Rhopalosiphum pseudobrassicæ* (Davis), Order Homoptera, Family Aphididæ.

ing In cases of bad infestation the entire plants become covered with a disgusting mass of the small, soggy lice, and the dying leaves and plants rapidly decay.

Plants Attacked.—The cabbage aphid is recorded from cabbage, cauliflower, Brussels sprouts, kohlrabi, collards, kale, turnip, and radish. The turnip aphid from cabbage, collards, kale, rape, mustard, rutabaga, lettuce, wild mustard, and shepherd's purse. Doubtless both occur on other plants of this family.

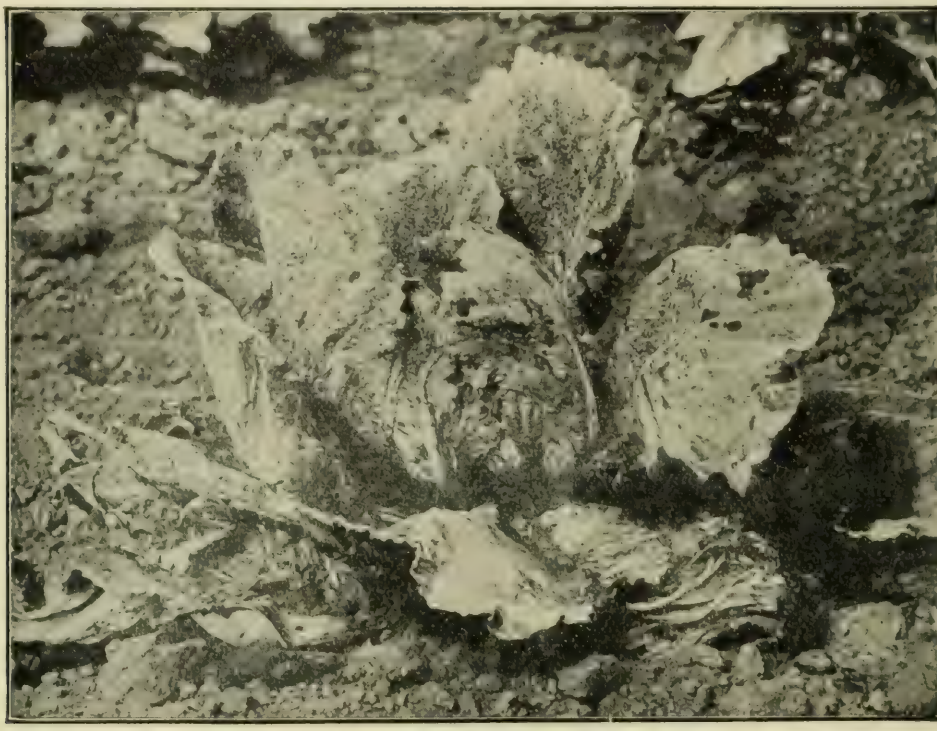


FIG. 328.—Head of cabbage ruined by the cabbage aphid. Note the numerous small lice on the leaves. (*From Ill. State Nat. Hist. Sur.*)

Distribution.—Both species probably occur throughout North America wherever their host plants grow.

Life History, Appearance, and Habits.—The life cycle is, in general, like that given as typical for aphids (see p. 442). The cabbage aphid winters in the northern states as small black fertilized eggs laid in depressions upon the petioles and underside of leaves of cabbage. The turnip aphid probably winters in a similar way, although the sexual individuals and eggs of this species have not been described. Farther south the species continue to reproduce ovoviviparously throughout the winter. In cage experiments, Paddock carried the turnip aphid through 25 generations in 12 months in Texas, while 16 generations of the cabbage aphid have been observed from April to October. When their food becomes unsatisfactory from any cause, winged females are developed which spread the species from plant to plant and start new families wherever

they alight. Each female commonly produces from 80 to 100 young during her lifetime of about a month.

Control Measures.—The control measures recommended for aphids on page 444 are effective for this species. Dusts containing 2.4 per cent nicotine (see p. 241) will penetrate into and under the leaves very effectively; and in some severe outbreaks have been found to be the most satisfactory means of control. On account of the wax powder that covers the bodies of the lice, and the tendency of the leaves to form pockets or cups in which the lice are protected, it is essential where sprays are used that very thorough applications be made, using an angle nozzle on the end of a 20-inch extension rod, and good pressure, and directing the spray from below against the under sides of the leaves and also downward into the heart of the plant. The destruction of the old stalks of cabbage and other crops as soon as the crop is harvested, will help to prevent destructive outbreaks of these aphids.

References.—*U. S. Dept. Agr. Dept. Circ.* 154, 1921; *Purdue Agr. Exp. Sta. Bull.* 185, 1916; *Tex. Agr. Exp. Sta. Bull.* 180, 1915.

Leaf Miners

This group of plants is often disfigured and damaged by several species of small flies that live in the maggot stage by eating the tissue of the leaves, between the upper and lower surfaces. Their feeding causes the production of large whitish blotches or blasted areas, or, in the case of the serpentine leaf miner,[1] slender, white, winding trails through the interior of the leaf. The leaves are greatly weakened and the mines serve as points where disease and decay may start, but the chief loss is to those vegetables of which the green leaves are eaten and which are rendered unattractive and unsalable by these flies. No practical control measures are known.

Reference.—*Jour. Agr. Research,* Vol. 1, pp. 59–87, 1913.

Cabbage Maggot[2]

Importance and Type of Injury.—Plants attacked by the cabbage maggot appear sickly, off color, and runty, and, if the attack is severe, wilt suddenly during the heat of the day and die. Roots of cabbage, cauliflower, rape, and the fleshy parts of turnips and radishes show brownish grooves over their surface and slimy winding channels running through the flesh, while many of the small fibrous roots are eaten off. Legless white maggots, from 1/4 to 1/3 inch long, blunt at the rear end and pointed in front, are often found in these burrows.

In most sections, early cabbage after transplanting, late cabbage while still in the seed bed, early turnips, and late spring radishes are most severely injured. Very early radish and late cabbage, after being set out, usually escape injury. The pest fluctuates much in abundance in different sections and years, but frequently 40 to 80 per cent of the plants

[1] *Agromyza pusilla* Meigen, Order Diptera, Family Agromyzidæ.

[2] *Hylemyia brassicæ* (Bouché), Order Diptera, Family Anthomyiidæ.

are destroyed, resulting in thousands of dollars' loss annually in many of the states where it occurs.

Plants Attacked.—This fly is chiefly injurious to plants of the mustard family or Cruciferæ, such as cabbage, cauliflower, radish, and turnip, but also attacks beet, cress, celery, and some other vegetables to a slight extent.

Distribution.—Introduced from Europe early in the nineteenth century, it has spread widely over North America. It is a serious pest in Canada and the northern part of the United States, but is seldom injurious south of the fortieth degree north latitude.

Life History, Appearance, and Habits.—This insect goes through the winter chiefly as a pupa in a hard, brown, egg-shaped puparium about 1/4 inch long, and buried from 1 to 5 inches in the soil. In spring, about the time early cabbage plants are set out (mid-May in the latitude of Chicago) the end of the puparium is broken open and a small gray fly emerges and crawls out of the soil. These flies (Fig. 329) are similar in general appearance to the common house fly but only about half as long (1/4 inch long); dark ashy gray with black stripes on the thorax and many black bristles over the body. The cells of the wing that open nearest to its tip are both wide open at the margin. They fly about close to the ground and deposit their small, white, finely-ridged eggs on the plants near where the stem meets the ground or in cracks and crevices in the soil. Three to seven days later, the eggs hatch and the very small maggots promptly seek the roots and eat into them. Each larva feeds for 3 to 4 weeks, and the roots often become riddled with their tunnels (Fig. 330). The larva has at the blunt rear end 12 short, pointed, fleshy processes arranged in a circle around the two button-like spiracles. The two processes nearest the middle line below are double-pointed.

Fig. 329.—Female of the cabbage maggot, *Hylemyia brassicæ* (Bouché). About twice natural size. (*From Can. Dept. Agr., Pamphlet* 32, *n.s.*)

When the maggots are abundant, the underground parts of the plants soon become honeycombed and rotten. Over 125 maggots have been taken from the roots of a single plant. Upon completing its growth the larva may pupate in its burrow, but more generally crawls away from the root into the soil a short distance and there forms its puparium. Two or three weeks later, on the average, the adults break out of the puparium and may push up through the soil from a depth of 6 inches or more. Undoubtedly some of these puparia of the first generation remain until the following Spring, but most of them transform to adults in late June and July, and lay eggs upon late cabbage and other plants. In most sections the injury from this second generation during dry midsummer

weather is not severe, since the insect requires cool, moist weather and succulent plants in which to thrive. Enough transform, however, to produce a partial third generation in autumn when they are sometimes very destructive to fall radishes and turnips. In some sections a partial fourth generation has been reported.

Fig. 330.—Root of cabbage showing cabbage maggots and their destructive work. (*From Can. Dept. Agr. Pamphlet* 32, *n.s.*)

Control Measures.—The most successful control is to treat the base of the plants and the adjoining soil with corrosive sublimate (bichloride of mercury), dissolved 1 ounce in 8 or 10 gallons of water. Three or four ounces (½ teacupful) of this solution is poured close around the base of each plant, wetting the stem as well as the surrounding soil, a few days after transplanting. A week to 10 days later the treatment is repeated, and one more treatment may be needed. The chemical should be dissolved in a small quantity of hot water in wooden, glass, or earthenware vessels and then diluted. The solution may be applied to a few plants by pouring from a sprinkling can with the "rose" removed or by means of a pail and dipper. More rapid application can be made from a knapsack-sprayer tank equipped with a short hose, a 2-foot extension rod, and a

pinch cock, allowing the liquid to run down by gravity to the base of the plant. For large areas, a barrel pump tank with two leads of hose and a man for each hose will be most efficient. *All metal containers should be thoroughly rinsed after using this solution in them, to prevent corrosion.* About 2 gallons of solution will be needed to treat a hundred plants. In transplanting, the above solution should be used instead of water to puddle the plants; and it may be used instead of water in transplanting machines.

In seed beds the material may be applied evenly all along the rows, using about one gallon to each 35 feet of row. On radishes, the row treatment should be applied shortly after the plants come up, and only one treatment will usually be needed.

Seed beds may be protected from these flies and from flea beetles and other pests by covering them with thin cloth, such as hospital gauze, having from 20 to 24 threads to the inch, securely tacked to the framework around the bed and supported by wires across the beds at intervals of 5 or 6 feet.

References.—*N. Y.* (*Geneva*) *Agr. Exp. Sta. Bull.* 442, 1917; and 419, 1916; *Proc. Entomol. Soc. Nova Scotia for* 1919, p. 41, 1920; *Dept. Agr. Canada*, *Entomol. Bull.* 12, pp. 9–29, 1916.

I. INSECTS INJURIOUS TO BEET, SPINACH, LETTUCE, CARROT, PARSNIP, CELERY, AND RELATED VEGETABLES

FIELD KEY FOR IDENTIFICATION

A. Insects chewing the foliage, tender stems or seed heads:

(*a*) *Caterpillars working under the protection of a silken web:*

1. Lettuce, beet, cabbage, cucurbits, pea, beans, potato, and tomato are attacked by yellowish-green worms, up to 1 inch long, with scattered hairs and conspicuous black spots feeding within light webs of silk that they spin over the plants, especially near the ground or in the soil. *Garden webworm*, page 396.

2. The flower heads of parsnip and celery are webbed together and devoured by small yellowish to grayish-green, black-spotted caterpillars, the largest about ⅗ inch long, which also mine in the stems. *Parsnip webworm*, page 509.

3. Celery, beet, and spinach foliage is ragged by greenish, watery-looking, white-striped caterpillars, the largest ¾ inch long, which work on the underside of leaves or fold and web the leaves together and feed within. Squirm actively when disturbed. *Greenhouse leaf tyer*, p. 714.

(*b*) *Insects feeding exposed on foliage:*

1. Large green caterpillars, up to 2 inches long, with a black cross-band and six yellow spots on each segment, eat the leaves of celery, parsnip, and carrot. *Black swallowtail butter fly*, p. 510.

2. Lettuce, celery, and beets are frequently attacked by a pale-green caterpillar, up to 1¼ inches long, narrowing gradually to the head, and with light and dark stripes. They have only three pairs of prolegs and consequently crawl with a looping movement. *Celery looper*, *Autographa falcigera* Kirby (see *Eleventh Rept. State Entomologist of Illinois*, pp. 38–43, 1882).

3. Small, greenish-black, hopping beetles, ¼ inch long, with a broad yellow collar behind the head, and grayish to purple, short, warty grubs (up to ⅓ inch long) eat small holes in the leaves or skeletonize them. *Spinach flea beetle*, page 510.

B. Insects sucking the sap from leaves and stems:

1. Broad, oval, black bugs, up to ⅒ inch long, convex above, suck the sap of celery and other plants causing the leaves to wilt and die. They give off a vile odor when crushed. *Negro bug*, page 511.

2. Slender, wedge-shaped, greenish or yellowish leafhoppers, under ⅛ inch long, suck sap of beets and poison them, causing the rolling and shriveling of leaves and the appearance of warts along the veins. *Beet leafhopper*, page 512.

3. Pale green or pinkish, winged or wingless aphids, only 1/12 inch long, suck the sap of spinach, beets, celery and about 100 other plants, causing stunting, wilting, and unmarketable condition of the plants. *Spinach aphid*, page 512.

C. Insects mining in the leaves:

1. Blister-like or blasted spots on the leaves of spinach, chard, and related plants are made by small maggots, not over ⅓ inch long, eating the interior of the leaf without consuming either surface. *Spinach leaf miner*, page 513.

D. Insects attacking the roots:

1. Yellowish-white maggots, about ⅓ inch long, chew off the small roots of celery and the bottom of the taproot of carrots and parsnips causing plants to yellow and make stunted growth. Roots may be riddled with rust-red burrows and surface scars. *Carrot rust fly*, page 514.

2. Stout, broad, reddish brown, spiny-legged beetles, ½ inch long by ¼ inch broad, gouge out unsightly holes in the roots of celery, carrots, parsnips, sugar beets, sunflowers, and other vegetables and field crops. *Carrot beetle*, page 514.

3. Aphids cluster on the roots of beets and other vegetables, sucking the sap and forming moldy, white-looking clumps. *Sugar-beet root aphid* and others, page 515.

4. Irregular dark grooves over the surface of carrots, or burrows through the roots, the latter sometimes containing fat, white, legless grubs. *Carrot weevil, Listronotus latiusculus* Boheman (see *Jour. Econ. Entomol.*, Vol. 19, pp. 490–496, 1926).

Parsnip Webworm[1]

Importance and Type of Injury.—The flower heads of parsnip and celery are webbed together with silk and devoured by small yellow, greenish or grayish caterpillars covered with small black spots and short hairs. They interfere seriously with the production of celery and parsnip seed. After consuming the unripe seed the caterpillars mine in the stems, and when full-grown are about ⅗ inch long.

Plants Attacked.—Parsnip, celery, wild parsnip, wild carrot, and related weeds.

Distribution.—South Canada and the Northern States east of the Mississippi.

Life History, Appearance, and Habits.—The grayish moth, an inch across the wings, winters under loose bark and in other protection and lays its eggs in late spring on the developing flower head and other parts of the plant. After destroying the flower buds and seeds, the caterpillars pupate in their mines, emerging as adults in late summer, when they seek

[1] *Depressaria heracliana* Linné, Order Lepidoptera, Family Œcophoridæ.

hibernating places. The insect is especially abundant on the heads of wild parsnips.

Control Measures.—Spraying or dusting with calcium arsenate at the rate of 6 to 8 pounds to the acre is an effective remedy, but much of the damage has usually been done before the caterpillars are noticed. Injured flower heads can be cut and burned in August, before the moths emerge. Wild host plants should be destroyed about the farm.

Black Swallowtail Butterfly[1]

Importance and Type of Injury.—Large green caterpillars, with a black crossband on each segment, which is indented by six yellow spots on its front margin, ranging up to 2 inches in length, eat the foliage of celery and related plants, stripping the leaves clean as they go (Fig. 140, *a*, *b*). They sometimes seriously injure young plants but are usually more noticeable because of their gaudy appearance than for the injury they do.

Plants Attacked.—Celery, dill, parsnip, carrot, parsley, caraway, and many other plants of the same family.

Distribution.—Throughout North America east of the Rocky Mountains. In the West it is replaced by the western parsley caterpillar.[2]

Life History, Appearance, and Habits.—In the northern States the winter is passed as a dirty, tan-colored chrysalid suspended from the host plants and other objects by a silk button and girdle, as described for the imported cabbage worm (see p. 495). The adults are large, black, swallowtail butterflies, expanding nearly 4 inches, with numerous yellow spots on the outer part of the wings and also a row of blue patches on the hind wing (Fig. 140, *c*). The eggs are scattered about on the leaves, in May and June, and hatch into the curious caterpillars. When disturbed, the caterpillars protrude from the head end two, soft, orange-colored horns (known as *osmateria*), that give off a sickening sweet odor which is probably a protection from some enemies. The larval stage lasts about a month, and the pupa stage 9 to 10 days in summer. There are two or three generations a year.

Control Measures.—Hand picking of the caterpillars, or dusting the plants with arsenate of lead or calcium arsenate, will easily destroy the worms. Poisons must not be applied to foliage vegetables ready to be put on the market.

Reference.—Scudder, "Butterflies of the Eastern United States," p. 1353, 1889.

Spinach Flea Beetle[3]

Importance and Type of Injury.—Small holes are eaten in the leaves, or the leaves are skeletonized from beneath, by small, jumping, greenish-

[1] *Papilio polyxenes* Fabricius, Order Lepidoptera, Family Papilionidæ.

[2] *Papilio zelicaon* Lucas, Order Lepidoptera, Family Papilionidæ.

[3] *Disonycha xanthomelæna* Dalman, Order Coleoptera, Family Chrysomelidæ.

black beetles with a yellow collar behind the head and by grayish to purple, warty, short, cylindrical worms, all under ¼ to ⅓ inch long.

Plants Attacked.—Spinach, beet, and pigweed, chickweed, lamb's quarters, and other weeds.

Distribution.—General east of the Rocky Mountains.

Life History, Appearance, and Habits.—The insect winters as a greenish-black, oval beetle ⅕ to ¼ inch long, with a yellow prothorax (Fig. 287). In April and May the beetles appear on the plants and lay small clusters of orange eggs (Fig. 285) placed on end at the base of the plant or on the soil near by. The dirty-gray to purplish young or larvæ (Fig. 286) feed on the underside of the leaves, becoming ¼ to ⅓ inch long within 2 to 4 weeks. They are very warty, cylindrical grubs, each wart terminating in a short black hair. When disturbed, the larvæ and beetles "play 'possum" and drop to the ground. A pupal stage of a week or 10 days is passed in the soil, and the new adults appear in July, lay eggs over a period of nearly 2 months, and the second generation matures before winter sets in.

Control Measures.—Dusting or spraying with stomach poisons readily kills the larvæ, and, if this is thoroughly done, the beetles will be killed or driven off.

Reference.—U. S. Dept. Agr. Bur. Entomol. Bull. 19, 1899.

NEGRO BUG[1]

FIG. 331.—The negro bug, *Thyreocoris pulicarius* Germar: adult, about ten times natural size. (*From Ill. State Nat. Hist. Sur.*)

Importance and Type of Injury.—Short, oval, black bugs (Fig. 331) about 1⁄10 inch long, together with small black and reddish nymphs, sometimes congregate on celery, corn, wheat, and other crops and suck out the sap, stunting the plants and causing the leaves to wilt and die. Outbreaks of the bug in Michigan and Ohio have destroyed thousands of dollars worth of celery, but the pest occurs only sporadically. Secretions of the bugs give a foul taste to raspberries and blackberries over which they crawl.

Plants Attacked.—Celery, corn, wheat, other grasses, some ornamental flowers, and many weeds, such as beggar-ticks, Lobelia, and Veronica.

Distribution.—Throughout the United States and Canada, east of the Rocky Mountains.

Life History, Appearance, and Habits.—The insects winter as adult bugs which are often mistaken for beetles because of the hard shell over the backs. This is not formed of the two wing covers but is a greatly enlarged thoracic shield, under the edges of which the wings slip when the bug comes to rest. The eggs are laid singly on the leaves and hatch in about 2 weeks into reddish nymphs which gradually grow into the form of the adult as they feed on the plants. They become adult by midsummer, and, after feeding for a few weeks, seek hibernating places long before cold weather.

Control Measures.—Weeds on which the bugs feed should be destroyed. When they attack cultivated crops a spray of nicotine sulphate 1 part to 500 parts of soapy water will kill all of the bugs hit by it.

Reference.—Mich. Agr. Exp. Sta. Bull. 102, 1893.

[1] *Thyreocoris pulicarius* Germar, Order Hemiptera, Family Cydnidæ.

Beet Leafhopper[1]

Importance and Type of Injury.—Beets are attacked by a disease known as "curly-leaf" or blight, which is caused by the feeding of a small leafhopper. This stunts the plants, kills them or greatly reduces the sugar content of the beets and the crop of seed. The leaf veins become warty, the veinlets transparent, the petioles kinked, and the leaves rolled upward at the edges, brittle, and shriveled. In many localities the growing of sugar beets has been abandoned because of this pest. The attack is generally sporadic, but there is no way of predicting when a destructive outbreak will occur. This insect is also the carrier of tomato yellows or curly top.

Plants Attacked.—Sugar beets, table beets, mangels, tomatoes and certain weeds.

Distribution.—Western United States east to Nebraska and Texas.

Life History, Appearance, and Habits.—The cause of the trouble known as curly leaf is a small, wedge-shaped leafhopper, of a pale greenish or yellow color, about ⅛ inch long, with long slender hind legs that enable it to jump quickly into the air. It also flies readily, and when flying looks like a tiny white fly. The adults winter on and about their wild food plants such as salt bush, Russian thistle, greasewood, and sea blite, and in the spring may fly for hundreds of miles in great swarms, alighting in beet fields wherever the crop is up. The adults, and later the nymphs, feed by inserting the slender mouth parts into the plant, introducing a poisonous or disease-producing substance that causes the curly-top condition to develop. The eggs are inserted full length into the veins, leaf-petioles, or stems, and hatch in 2 weeks to tiny, pale-colored, wingless nymphs that settle in the center of the plant. In from 3 weeks to 2 months the bugs are full-grown. There may be from one to three or more generations.

Control Measures.—Curly-leaf is caused only by the feeding of the leafhopper, but no practical control measure for the bug has been discovered. It flies so readily that it is hard to destroy by contact sprays or dusts. Early planting and thorough cultivation are recommended to produce a crop in spite of the presence of the hoppers.

References.—*Utah Agr. Exp. Sta. Bull.* 155, 1917; *Jour. Agr. Research*, Vol. 20, p. 245, 1920; *Hilgardia*, Vol. 3, No. 2, May, 1928.

Spinach Aphid[2]

This insect, which is further discussed as the green peach aphid, has been very destructive to spinach in the large trucking sections of the Atlantic coast. It has been estimated that $750,000 worth of damage was done to the spinach crop in Virginia in a single year (1907). It also attacks celery, lettuce, beets, tomato, egg-

[1] *Eutettix tenellus* (Baker), Order Homoptera, Family Cicadellidæ

[2] *Myzus persicæ* (Sulzer), Order Homoptera, Family Aphididæ.

plant, potato, the Cruciferæ, cucurbits, and other vegetables. Its life cycle on the peach is discussed on page 610. On spinach and other vegetables the best control is the use of a 3 per cent nicotine dust, at the rate of 30 or more pounds per acre.

Spinach Leaf Miner[1]

Importance and Type of Injury.—Blasted spots or blister-like blotches appear on the leaves of spinach, chard, and related plants, where small maggots have eaten out the tissue of the leaf between upper and lower surfaces. The leaf vegetables are rendered unfit for greens, and the

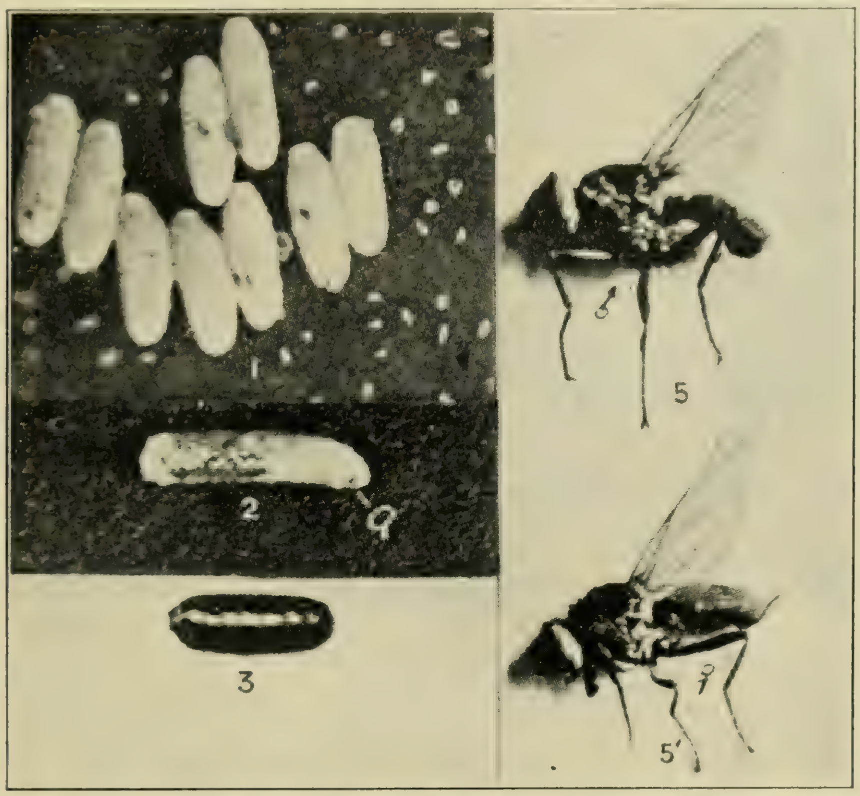


Fig. 332.—Spinach leaf miner, *Pegomyia hyoscyami* Panzer: 1, eggs on leaf, greatly magnified; 2, maggot or larva, the mouth hooks at *a*; 3, puparium: 5, male adult above; 5′ female adult, about four times natural size. (*From N. Y. (Geneva) Agr. Exp. Sta. Bull.* 99.)

development of seeds and roots, such as beets, is decreased by the partial defoliation.

Plants Attacked.—Spinach, beet, sugar beet, chard, mango, and many weeds, including chickweed, lamb's quarters, and nightshade.

Distribution.—Probably introduced from Europe previous to 1880, it is now generally distributed over the United States and Canada.

Life History, Appearance, and Habits.—The winter is probably passed mostly in puparia (Fig. 332, 3) in the soil. In April and May the slender-bodied, grayish, black-haired, two-winged flies (5), about ¼ inch long, appear in the fields, and the females deposit small white

[1] *Pegomyia hyoscyami* Panzer, Order Diptera, Family Anthomyiidæ.

eggs (Fig. 332, 1), one to five in a place, on the underside of the leaves. Upon hatching, the tiny maggot at first eats a slender, winding mine in the leaf, but as it increases in size the mine is widened to form a blotch that often joins the mines of other maggots in the same leaf. The maggots (2) may migrate from leaf to leaf, and become full-grown in 1 to 3 weeks. Pupation takes place chiefly in the upper 2 or 3 inches of the soil, but some transform among trash on the ground or even in the larval mines. Within 2 to 4 weeks the adults appear from the pupæ and start a new generation. Three or four generations may be completed during the season.

Control Measures.—The increase of the flies may be checked by destroying their host weeds. No practical control has been developed.

References.—*N. Y. (Geneva) Agr. Exp. Sta. Bull.* 99, 1896; *Ann. Applied Biology*, Vol. 1, pp. 43–76, 1914.

Carrot Rust Fly[1]

Importance and Type of Injury.—Celery plants, after getting a good start, wilt, and the outer leaves turn yellow, on account of the eating off of most of the fibrous roots by a very slender yellowish-white, legless maggot, about ⅓ inch long when full-grown. Carrots and parsnips become stunted, and the lower end of the taproot is found to be eaten off. In severe attacks, the entire root becomes scarred and riddled with the burrows of the larvæ, the burrows taking on a rust-red color. Injury may continue in stored carrots if the temperature is favorable.

Plants Attacked.—Carrots, parsnips, celery, parsley, celeriac, wild carrots.

Distribution.—Starting near Ottawa in 1885, as an importation from Europe, the insect has spread over much of eastern Canada and the United States as far west as Oregon.

Life History, Appearance, and Habits.—The winter is passed in the slender brown puparia, about ⅕ inch long, buried in the soil, or as maggots in the roots. The flies are abroad in May, and deposit eggs about the base of the plants from which the maggots issue and work down in the soil to attack the tender tip of the root. As they increase in size and numbers, nearly the entire root system may be destroyed during the month or more while the larvæ are growing. The pupal stage is passed in the soil near the roots, and a partial second brood of flies emerges in August to attack late carrots and celery.

Control Measures.—No practical control for this insect has been worked out, but it is possible that the control with Bordeaux-oil emulsion recommended for the onion maggot would be effective against this insect (see page 492).

Reference.—*U. S. Dept. Agr. Bur. Entomol. Bull.* 33, 1902.

Carrot Beetle[2]

Importance and Type of Injury.—The roots of celery, carrot, and parsnip are gouged by the feeding of broad, reddish-brown, stout-legged beetles, about ½ inch long, and slightly over half as wide (Fig. 333).

Plants Attacked.—Carrot, parsnip, celery, beet, potato, cabbage, corn, cotton, sunflower, dahlia, and other crops, and weeds, especially Amaranthus.

Distribution.—Over much of the United States except the most northern states.

[1] *Psila rosæ* Fabricius, Order Diptera, Family Psilidæ.

[2] *Ligyrus gibbosus* De Geer, Order Coleoptera, Family Scarabæidæ.

Life History, Appearance, and Habits.—The adult beetles winter in the soil to a depth of 4 feet, emerge in spring and lay eggs at night in the soil. The eggs increase greatly in size before hatching. The larvæ resemble the common white grubs, being curved and white with a bluish cast and red-brown heads. They feed largely on grasses and decaying vegetation in the soil, but often attack the roots of crops, a dozen or more beetles sometimes being found around a single plant. A generation is completed in a year, the adults being present and injurious from late April to August.

Control Measures.—No successful control measure is known.

Reference.—Jour. Econ. Entomol., Vol. 10, p. 253, 1917.

Fig. 333.—The carrot beetle, *Ligyrus gibbosus* De Geer, adult. The line indicates natural size. (*From Ill. State Nat. Hist. Sur.*)

Sugar-beet Root Aphid[1]

Aphids are frequently found on the roots of the vegetables in this group. One of the most destructive is the sugar-beet root aphid, which is found in the western half of the United States on the roots of sugar beets, beets, mangels, and many weeds, such as lamb's quarters, yarrow, dock, goldenrod, and grasses. It reduces both the size and the quality of the beets by sucking the sap from the roots.

The insects winter in part as fertilized eggs on the bark of poplar trees, and in part as wingless females on the roots of herbaceous plants. The insects are yellow in color and have a mass of fine cottony-looking, waxy threads toward the end of the body, so as to appear like white mold on the roots. A migration of winged aphids from the poplars to beets takes place in July, and a return migration to poplars in September and October.

Control Measures.—Where beets are grown on irrigated land, aphids can be kept in control and the yields increased by giving five or more irrigations at 10-day intervals, during July and August.

Reference.—Jour. Econ. Entomol., Vol. 7, pp. 136–141, 1914.

J. INSECTS INJURIOUS TO ASPARAGUS

FIELD KEY FOR THE DETERMINATION OF INSECTS INJURING ASPARAGUS

1. Young shoots are gouged and scarred and, later in the season, the foliage is devoured and the stems scarred, by hordes of brilliant, blue-, red-, and yellow-spotted beetles, about ¼ inch long, and by their slug-like, dull-gray larvæ. Eggs, $\frac{1}{16}$ inch long, and dark brown are found standing on end in rows like the teeth of a comb, along the stems and leaves. *Asparagus beetle,* page 516.

2. New shoots, foliage, and stems scarred and chewed by a light-brown to reddish orange, rather straight-sided beetle, a little over ¼ inch long, with six small black spots scattered over each wing cover. Orange to brownish larvæ ⅓ inch long feed mostly in the berries. Eggs laid flat on their sides. *Twelve-spotted asparagus beetle,* page 517.

3. Whitish, legless and headless maggots, up to ⅕ inch long, mine beneath the epidermis of the stems, sometimes girdling the plants and causing them to yellow and

[1] *Pemphigus betæ* Doane, Order Homoptera, Family Aphididæ.

die. Adults are small, black, shiny two-winged flies, 1/6 inch long. *Asparagus miner*, page 518.

Asparagus Beetle[1]

Importance and Type of Injury.—Wherever asparagus is grown, in the area infested by this insect, the voracious beetles (Fig. 334) make their appearance as soon as the shoots push above the soil in the spring. They gnaw out the tender buds at the tips and cause the tips to be scarred and browned. The eggs are also deposited in great numbers on the tips and make the plants unfit for sale. After the leaves come out, the beetles and their grayish slug-like larvæ gnaw the surface of the stems and devour the leaves, thus robbing the root system of the food materials needed to form a good crop of shoots the following season. The larvæ also excrete a black fluid that stains the plants. The injury is especially serious in new beds.

Plants Attacked.—Asparagus only, so far as known.

Distribution.—The northeastern fourth of the United States, from Missouri eastward and from Tennessee and North Carolina northward into Canada; also throughout much of California and Colorado and Oregon. The insect is an importation from Europe, first found in America on Long Island in 1860. In Illinois it first became destructive from 1910 to 1915.

Life History, Appearance, and Habits.—The beetles winter in sheltered places such as decayed or split fence posts and under loose bark of trees. Egg laying begins soon after they appear in the field in April or May. Shoots of asparagus are often seen which are literally blackened by hundreds of eggs, all standing on end in rows of from three to eight (Fig. 334). The eggs hatch within a week, and the very small grubs migrate to the tips of the leaves and begin feeding upon them. The later stages are similar to the young except for a gradual increase in size up to 1/3 inch long. The color is dull gray, with black head and legs. The body is smooth and the abdomen provided with short prolegs. After feeding for 10 days to 2 weeks, the larvæ disappear into the soil and form a yellowish pupa. A week or two later the new adults emerge from the soil and promptly start another generation. Each generation requires from 3 to 7 or 8 weeks, and there are from two to five generations in the course of a year. Cold weather kills the eggs and larvæ and drives the beetles into hibernation. The insect appears to be much less destructive in wet seasons. The appearance of the adult is described in the key (p. 515).

Control Measures.—Newly set beds should be sprayed or dusted with arsenate of lead as soon as the beetles appear and again after the foliage is fully formed. For a spray, use 3 pounds arsenate of lead and 3 pounds of soap in 50 gallons of water. Keeping down volunteer plants and

[1] *Crioceris asparagi* Linné, Order Coleoptera, Family Chrysomelidæ.

cutting the shoots very clean every day or two will tend to remove the eggs before the larvæ can establish themselves in the patch. A few plants here and there may be left to grow and kept covered with the spray. After cutting season the plants should be dusted with arsenate of lead, 1 part to 8 or 10 parts of lime, or sprayed as recommended above, not only to lessen the injury to the development of the plants, but also to reduce

FIG. 334.—Asparagus beetle, *Crioceris asparagi* Linné. At left, eggs on asparagus shoots, natural size; at right, adult and larva, about four times natural size. (*From Conn. Agr. Exp. Sta. 45th Rept.*, 1921.)

the number of beetles the following spring. The spray may be applied with a potato sprayer by raising the booms high enough to avoid injuring the plants.

Reference.—U. S. Dept. Agr. Farmers' Bull. 837, 1917.

TWELVE-SPOTTED ASPARAGUS BEETLE[1]

Importance and Type of Injury.—Injury by the adult is the same as by the asparagus beetle, and the gnawing is especially noticeable on the young shoots. The larvæ,

[1] *Crioceris duodecimpunctata* Linné, Order Coleoptera, Family Chrysomelidæ.

however, do little damage, since they feed almost entirely in the fruits or berries. In some sections this species is more abundant and destructive than the former.

Plants Attacked.—Asparagus only.

Distribution.—Imported from Europe some time previous to 1881, when it was reported in Maryland, the insect has now spread over much the same territory as the asparagus beetle. It was first taken in Illinois in 1925; it has not been recorded from the states west of the Mississippi.

Life History, Appearance, and Habits.—The life history is similar to that of its close relative, described above. The adults, which are briefly described in the key, appear a little later in the spring and do not lay eggs until shortly before the berries form. The dark-green eggs are glued on their sides to the leaves and hatch in 1 to 2 weeks. The larvæ, before they become full-grown, usually destroy three or four berries, by eating out the seeds. Pupation takes place in the soil. The new adults (Fig. 335) appear in late July and another generation in early September.

Fig. 335.—Twelve-spotted asparagus beetles, *Crioceris duodecimpunctata* Linné. Four times natural size. (*From Conn. Agr. Exp. Sta. 45th Rept.*, 1921.)

Control Measures.—The same as for the asparagus beetle.

References.—*U. S. Dept. Agr. Farmers' Bull.* 837, 1917; *N. Y.* (*Geneva*) *Agr. Exp. Sta. Bull.* 331, 1913.

Asparagus Miner[1]

Importance and Type of Injury.—The maggots of this small fly mine up and down the stems of asparagus just beneath the surface, near the base of the plant. Where abundant they may girdle the plants, causing the foliage to yellow and die prematurely.

Plants Attacked.—Asparagus.

Distribution.—Northeastern United States and southern Canada and also California.

Life History, Appearance, and Habits.—The insect winters in puparia in the larval tunnels under the epidermis of the stems and from 1 to 6 inches below the surface of the soil. The flies appear in the fields the latter half of May and thrust their eggs beneath the epidermis of the stem near or below the surface of the soil. The egg stage lasts 2 or 3 weeks, and the larvæ feed for about the same period before pupating. In 3 weeks more, chiefly in July, the new adults are abroad, and the second-generation larvæ mine in the stems during late summer. There are two generations a year.

Control Measures.—The rust-resistant strains of asparagus are said to be less injured by this insect. If old stalks are pulled up and burned, the puparia in the stems will largely be destroyed. Spraying with nicotine sulphate 1 part to 500 parts of soapy water, will destroy many of the larvæ in their galleries. In irrigated districts, winter flooding is recommended.

References.—*U. S. Dept. Agr. Bur. Entomol. Circ.* 135, 1911; *N. Y.* (*Cornell*) *Agr. Exp. Sta. Bull.* 331, 1913.

K. INSECTS INJURIOUS TO SWEET CORN

The insects of sweet corn are, without exception, the same as those of field corn, already discussed in Chapter XI. One of the most destructive to sweet corn is the corn earworm, which eats the kernels at the end of the

[1] *Agromyza simplex* Loew, Order Diptera, Family Agromyzidæ.

ears (see p. 350). In seasons when this insect is abundant, nearly every ear will be attacked by the worms, rendering the ears repulsive to the consumer and causing almost insurmountable difficulties to the canners. Sometimes the ends of lightly infested ears are cut off before marketing, thus removing most of the worms. The insect can be controlled on sweet corn by dusting the silk at the ends of the ears with arsenate of lead or calcium arsenate, mixed with equal parts of very fine dusting sulfur, conveniently applied with a puff duster. This poisons many of the worms as they eat their way through the silk to the ear. Since the ears do not all silk at once and the eggs hatch over a long period of time it is necessary to make three to five applications at intervals of 5 days. The cost is about $10 an acre for the season. If corn can be produced to be past the fresh-silk stage before the moths become abundant, they will pass it by and lay eggs elsewhere. In the latitude of northern Illinois, early-maturing or early-planted corn is injured least, while in the latitude of central and southern Illinois medium plantings suffer least.

In the area where it is abundant, the European corn borer is by far the most destructive pest of sweet corn. Sweet corn is more severely injured than field corn because of the smaller stalks. The control of this pest so far as it has been developed is given on page 336.

The soil-infesting larvæ such as white grubs, wireworms, and cutworms are especially destructive to gardens when planted on sod land. This practice should never be followed. Sod land that is to be put to trucking should be seeded to clover, alfalfa, or small grains for at least one year. Gardens surrounded by the favored food trees of the May beetles are especially liable to injury by white grubs every year.

Since corn insects of many kinds, notably the northern corn rootworm and corn root aphid, accumulate and increase in numbers when corn is planted year after year on the same soil, sweet corn should not be planted in fields that have been in corn for several years. Sweet corn will never be injured severely by the northern corn rootworm unless grown in soil that has been in corn for 1 or more years previously. For the corn root aphid, the cultivation of the soil suggested on page 317 will be most effective.

Army worms and grasshoppers are periodically very destructive, but can always be brought under control by the use of poisoned-bran bait. It may be necessary in the case of small gardens, to apply the poisoned bait to surrounding fields. Keeping down the growth of weeds about gardens will help in the control of many pests of corn, especially the corn root aphid and the common stalk borer.

For further information regarding the special control of insects on sweet corn, see pages 300 to 353.

CHAPTER XVII

INSECTS INJURIOUS TO DECIDUOUS FRUITS AND BUSH FRUITS

A large number of insects find their favorite or only food supply on the roots, trunk, branches, leaves, or fruit of our deciduous tree and bush fruits. Many of the insects which formerly fed on the fruits or foliage of uncultivated plants have found the abundant food supply furnished by large orchards or plantations of the bush fruits much to their liking, and now feed almost exclusively on these cultivated crops. The world-wide commerce in fruits and fruit-producing plants has led to the importation and general spread of many serious fruit pests in this and other countries. In most parts of this country it is now impossible to produce marketable fruit, regardless of the fertility of the soil, favorable climate or varieties grown, unless the insects are controlled. In other words, insects have come to be the limiting factor in fruit production.

In the United States and Canada, fruit trees are subject to attack by many insects, among which are several that, in a single season, may ruin the crop or even destroy the trees of a well-established, mature orchard. The most important of these fruit insects are discussed in the following order:

General Reference.—Slingerland and Crosby, "Manual of Fruit Insects," The Macmillan Company, 1915.

A. APPLE INSECTS

FIELD KEY FOR THE IDENTIFICATION OF INSECTS INJURING THE APPLE

A. Insects that bore into the trunk and branches:

1. Shallow, irregular burrows in the inner bark, mostly on the sunny sides of apple and other trees. During the early summer months, dark, olive-gray, flattened beetles, about ½ inch long, blunt at the head end and tapering to a rounded point at the tail, and with metallic-colored, roughened, wing covers will be found on the sunny parts of the trunk and branches. White, flattened, legless grubs from ½ to 1 inch long, with the body greatly enlarged just behind the head, are found in the shallow burrows under the bark. *Flat-headed apple-tree borer*, page 526.

2. Nearly round holes, a little larger than a lead pencil, in the lower parts of the trunks of apple trees. Bits of yellowish-brown frass or sawdust forced from small holes in the bark at the base of apple trees. Yellowish-white, legless grubs up to 1 inch long, with strong brown jaws and body enlarged but not flattened just behind the head, bore in the inner bark and wood of trees about the base. Velvety brown, cylindrical beetles, about 1 inch long, with two conspicuous white stripes on the back, crawling over the trunk and feeding on the foliage of apple from June to September. *Round-headed apple-tree borer*, page 527.

3. Many small round holes, about the size of a No. 6 shot, in the bark of the trunk and branches of apple; seldom occur except on trees lacking in vigor. Small, black beetles about ⅒ inch long, the body blunt at either end, crawling over the bark and excavating small holes, usually starting at the base of a bud or twig. Underneath the bark are numerous, fine, sawdust-filled burrows up to 4 inches in length, radiating from a short parent gallery, and often containing small white grubs. *Shot-hole borer*, page 530.

4. Small holes through the bark of apple somewhat smaller than *A*, 3, but extending directly into the wood, where they branch several times. Burrows in the wood usually stained a dark color. Brownish, or brownish-black, blunt-ended, minute beetles, working in these holes and occasionally crawling over the bark of the tree. *Pin-hole borers*, page 532.

B. Insects that injure apple twigs and branches:

1. Twigs and small branches of apple, up to 2 feet in length, are pruned off, especially on young trees. Injury occurs during May and the first of June. At this time, large grayish snout beetles, nearly ¾ inch long, with bodies spotted with black, may be found resting on the trees, or cutting off the twigs and buds. Injury occurs only in the vicinity of woodlands or on newly cleared ground. *New York weevil*, page 532.

2. Buds of apple and the newly set fruit cut off by grayish, plump-bodied, snout beetles, slightly smaller than *B*, 1. Beetles are about ½ inch in length, of a greenish-gray color, with two irregular light bands across the wing covers. The wing covers are bent down at the end and terminate in an acute angle. Body covered with overlapping scales. *Imbricated snout beetle*, page 533.

3. Twigs and small branches of apple and many other trees split and scored where bark of twigs has been pushed back and the wood at short intervals raised in small bundles of splinters, with double row of egg punctures beneath. During May and June, wedge-shaped, transparent-winged, black-bodied insects, about 1½ inches long, blunt at the head end and with conspicuous eyes at each corner of the head, resting on the foliage, or flying about the trees. Many of them utter a shrill, high-pitched song. *Periodical cicada*, or *seventeen-year locust*, page 533.

4. Double rows of punctures or slits, about ¼ inch long, in the bark of twigs and branches, usually most abundant in trees standing in sod or surrounded by weeds and grasses. Slits are crescent shaped and farthest apart at the middle. The scars

remain on the injured twigs for several years. In the late summer and early fall, small, triangular, green, very active, jumping insects, about the size and shape of a beech nut, make these punctures in the twigs, in which their eggs are deposited. *Buffalo treehopper*, page 537.

C. Insects that suck the sap of the apple:

1. Small gray or brownish-gray spots about $\frac{1}{16}$ inch across, each with a central nipple, on twigs and fruit, often surrounded by reddish or pinkish, inflamed-appearing areas. Twigs covered with a gray coating, having the appearance of ashes. If the larger grayish dots on the bark are lifted, a lemon-yellow, soft-bodied creature, nearly the size of a pinhead, will be found beneath. Trees where the grayish covering occurs on the trunk and branches have thin, yellow, spotted foliage, often in a dying condition. *San Jose scalé*, page 539.

2. Grayish-white, pear-shaped, flat scales, about $\frac{1}{8}$ inch long, adhering tightly to the bark of branches and trunk. Smaller, three-ridged, straight-sided scales scattered among the larger pear-shaped individuals. In the winter, the larger grayish-white scales will be found to cover a number of small reddish-purple eggs. In the summer, a yellowish, soft-bodied sucking insect will be found under the scale. *Scurfy scale*, page 543.

3. Brownish to grayish-brown, hard, polished scales, very closely resembling a half oyster shell in appearance, and about $\frac{1}{8}$ inch in length, by one-third as wide, adhering tightly to the bark of the apple, so thick as to overlap. In the winter, from 40 to 60 pearly-white eggs will be found under most of the larger scales. Scales often in patches on the bark. Heavily infested trees lacking in vigor or dying. Fruit sometimes specked with scales, but usually lacking in reddened areas such as occur around San José scale. *Apple oyster-shell scale*, page 544.

4. Greenish-black, shiny eggs about the tips and buds of twigs. Many small, soft-bodied, sucking aphids, clustered on the buds or curling the newly formed leaves of apple trees in the spring. The feeding causes the dwarfing of the fruit, or practically stops growth, although the apples remain on the tree. Winged and wingless aphids will be found after the time of bloom. Bodies of the insects with a distinct waxy coating, some of them with a pinkish tinge. These aphids migrate from the tree by early summer. *Rosy apple aphid*, page 545.

5. Dark, greenish-black, shiny eggs about the buds and in crevices in the bark during the winter. Soft, green-bodied aphids appear on the buds as soon as the green begins to show in the spring. These aphids continue to feed on the buds, new growth, and water sprouts throughout the summer, often causing a curling of the new growth. Some dwarfing of apples, as in *C*, 4. *Green apple aphid*, page 549.

6. Shiny, greenish-black eggs on twigs and bark as in *C*, 5. Large numbers of green-bodied aphids clustered on the opening buds. They nearly all leave the apple before the time of bloom. Injury by this species is very slight. *Oat aphid* or *apple-grain aphid*, page 549.

7. White, cottony masses of waxlike material covering the backs of dark purplish-brown aphids about $\frac{1}{20}$ inch long, which cluster on wounds along the trunk and branches of apple and other trees. Large knots on the roots and underground parts of the stem, often with short, fibrous roots extending from the knotted areas. *Woolly apple aphid*, page 550.

8. Small greenish, active, slender, winged insects, about $\frac{1}{8}$ inch long, accompanied by pale, greenish-white, wingless, active nymphs, sucking the sap from the underside of leaves of apple. Foliage of infested trees pale in color, with small white dots showing on the leaf; new foliage curled, leaf margins slightly burned; and very small black specks of excrement on the fruit. *Apple leafhoppers*, page 552.

9. Large numbers of reddish, minute, rounded eggs on the ends of twigs of apple during the winter. Very small, yellowish-green or reddish, eight-legged mites, about

$\frac{1}{50}$ inch long, feeding on the underside of foliage of apple and other trees. Infested foliage has a pale, sickly appearance. Numerous delicate webs over the foliage and other parts of the tree. *Red spider*, page 448.

10. Similar to *C*, 9, but eggs somewhat larger and more reddish in color, often occurring in such numbers as to give a reddish tinge to the twigs. Infested trees with pale foliage which sometimes drops off during late summer. Small, eight-legged, reddish mites about $\frac{1}{30}$ inch long, with very long front legs, working on the underside of the foliage. *Clover mite*, page 553.

11. Leaves of apple, plum, peach, and other fruits show a pale, sickly appearance, or with brownish red specks. At a distance, foliage has the appearance of being dusty. Very light webs over the surface of the leaves, upon which are crawling minute, reddish, eight-legged mites. *European red mite*, p. 554.

12. Very small, elongated, four-legged whitish mites, about $\frac{1}{125}$ inch in length, under bark of trees during the winter. Dark brown, blister-like, scabby areas on the leaves and occasionally on the fruit. Badly infested trees with distinct yellowish tinge to the foliage. *Pear leaf blister mite*, page 590.

D. Insects that eat the leaves:

1. Very small, dull-black, snout beetles about $\frac{1}{10}$ inch long, which hop vigorously when disturbed, eat small holes in the underside of leaves from the time when the foliage first starts until midsummer. Foliage of heavily infested trees has the appearance of having been riddled with fine bird shot. Yellowish-brown mines start near the center of the leaf and run to conspicuous blister-like cells in the outer leaf margin. *Apple flea weevil*, page 558.

2. Foliage of apple skeletonized and eaten off by grayish or brownish measuring worms about 1 inch in length, with three pairs of legs near the head and two pairs of prolegs near the end of the body. Damage occurs in the spring about the time the trees have come into full foliage. Injured trees have the appearance of having been scorched by fire. The caterpillars causing the injury spin down from the foliage on silken threads when the trees are jarred or the insects are disturbed. Grayish, wingless, soft-bodied, spider-like moths, crawling up the trunk of the trees in the spring and mating with grayish-brown males, with wings about $1\frac{1}{2}$ inches across. *Spring cankerworm*, page 555.

3. Injury and appearance of insects the same as in *D*, 2, except the moths appear on trunks of trees during the fall, and the caterpillars have three pairs of prolegs instead of two. Injury to the trees occurs at the same time in the spring. *Fall cankerworm*, page 557.

4. Leaves, especially those at tips of new growth near the top of the tree, skeletonized or eaten out in part, by dark green, active caterpillars with four shining black tubercles on the back just behind the head. Caterpillars web two or three leaves together and feed within the enclosed area. Injury is most severe during the late summer and early fall. *Apple leaf skeletonizer*, page 559.

5. Very tough, blackish, conspicuously curled cases, about $\frac{3}{4}$ inch long, usually partly enclosed in one or two dead leaves, attached to the ends of twigs and in the forks of small twigs during the winter. Cases enclose dark brown hairy caterpillars, about $\frac{1}{3}$ inch long, which eat out the opening buds in the spring. Fruit sometimes specked with small feeding punctures during August. *Leaf crumpler*, page 560.

6. Tiny, brownish-gray, tough, silken cases about $\frac{1}{6}$ inch long, bent at the top, so that they roughly resemble a pistol in outline, standing out at right angles to twigs and branches during the winter. Brown worms, about $\frac{1}{8}$ inch long, sheltering in these cases, feed on the newly opening buds in the spring, and on the fruit and foliage during the late summer. *Pistol-case bearer*, page 561.

7. Cases attached at right angles on the twigs and branches as in *D*, 6, but cases not bent over at the top. In the spring the insect moves about over the leaves eating or mining out small areas. *Cigar-case bearer*, page 563.

8. The newly opening buds and leaves of the apple are fed upon by a small brown worm, about ¼ inch long, with a black head; leaves and buds webbed with silk where the worm is feeding. In the winter small silken cases containing brown worms are attached to the axil of the bud or twig. Fruit on infested twigs often shows small areas of feeding, somewhat resembling injury by late codling-moth larvæ. *Bud worms* or *bud moths*, page 563.

9. Loosely woven white webs, enclosing the leaves of several branches, within which very hairy, pale-yellow, black-spotted caterpillars may be found feeding on the protected foliage. Caterpillars are about 1¼ inches long when full-grown. The webs contain black pellets of excrement, giving them an unsightly appearance. Injury most conspicuous in the late summer and early fall. *Fall webworm*, page 564.

10. Large, thick, white webs in the forks or crotches of trees in the early spring; leaves stripped from the branches within a considerable distance of these nests. Brownish-black, hairy caterpillars, ½ inch to 2 inches in length, with a light stripe down the back, sheltering within the webs during the day time, or feeding on the new foliage. Silken roadways, or paths leading from the web to other parts of the tree. Small, shiny, varnished appearing, black egg masses, about ½ inch long, encircle small twigs during the winter. *Eastern tent caterpillar*, page 565.

11. Apple leaves skeletonized by yellow-striped, hairy caterpillars, up to 1½ inches in length, with two pencil-like tufts of long black hairs projecting in front, and a single similar tuft projecting backward from near the tail. Frothy, white, egg masses, about ½ inch across, attached to grayish, hairy, empty cocoons on folded dead leaves or bark will be found on the twigs and branches of infested trees during the winter. *White-marked tussock moth*, page 687.

12. During the winter season, several leaves tightly webbed together and firmly attached to a twig near the tip of a branch, enclose from 25 to several hundred small, dark-brown, very hairy caterpillars about ¼ inch long. If caterpillars or their hairs come in contact with the skin, a distinct burning or itching results, which may persist for several days. White moths, with brown abdomens, flying in great numbers at night, during July. The moths are strongly attracted to lights. *Brown-tail moth*, page 692.

13. Pale-yellow masses of eggs about 1 inch across, with a felt-like covering of tawny hairs, attached to the bark of trees, or on buildings, walls and other objects during the winter. Somewhat flattened, bluish, stiff-haired caterpillars, feed on the foliage of all kinds of deciduous trees and also upon evergreens. Caterpillars with five pairs of conspicuous bluish tubercles on the back, behind the head, followed by six pairs of somewhat larger, red tubercles on the following segments. Foliage often completely stripped from trees in infested areas. *Gypsy moth*, page 690.

14. Yellow- and black-striped caterpillars, with a distinct, ridged, yellow ring about the neck, or with a red hump just back of the head with a row of black spines projecting from it, feed, many together, on the foliage during the summer and early fall. Caterpillars, when full grown, are 1½ to 2 inches in length. They rear head and tail when disturbed. Small trees, or single branches on large trees, completely stripped of leaves by these caterpillars. *Yellow-necked* and *red-humped caterpillars*, page 566.

15. Brownish or grayish, winged, vigorously jumping insects, from 1 to 2 inches in length, with conspicuous heads and eyes, feed on the foliage of apple during the late summer, sometimes stripping the trees and scoring the bark. *Grasshoppers*, page 567.

E. Insects that attack the fruit:

1. Apples with holes eaten in the flesh of the fruit, the burrow generally running to the core, and seeds more or less injured. Masses of dark castings often protruding from these holes especially at the calyx. Pinkish-white, brown-headed worms, about ¾ inch long, feeding inside the apple, or resting in tough cocoons of white silk, spun under the bark on the trunk or in other shelters about the tree. Minute, flat, white, shiny eggs, three-fourths the size of a pinhead, on the leaves adjacent to the growing apples or on the skin of the apple. *Codling moth*, page 568.

2. Injury similar to *E*, 1, but holes in the apple about half the size, seldom reaching the core, usually going in from the side of the fruit. Areas of varying size where the larva has eaten under the skin, without feeding deeply on the flesh. *Lesser apple worm*, page 573.

3. Large, irregular cavities eaten in the sides of small apples, from 1 to 3 weeks after the fruit has set. Green worms about ¾ inch long, sometimes with fine stripes on the sides, are found on the twig or branch adjacent to the injured apple or actively feeding on the apple. Apples at picking time deformed or misshapen, with brown, healed-over cavities in the sides. *Green fruit worms*, page 574.

4. Injury resembling *E*, 3, but injured areas much more shallow, often merely the surface of the apple eaten away. Injury most common where the leaves rest against the fruit. Very active, translucent, greenish worms, with four white stripes on the back, the outer stripes broader than the inner ones, feeding on the fruit, or skeletonizing the leaves during early summer. Worms about ½ inch long when full grown. *Palmer worms, Dichomeris ligulella* Hübner (see *N. Y.* (*Cornell*) *Agr. Exp. Sta. Bull.* 187, 1901).

5. Injury similar to *E*, 3, but usually including nearly all the apples on a branch. Foliage ragged and buds eaten off by small, greenish-brown, very active worms about ¾ inch long when full grown. Injury occurs from the time the buds separate, until about 4 weeks thereafter. Injured leaves rolled, folded, or drawn together about the fruit with light silken threads. Apples at picking time with brown, scarred areas in the sides. *Fruit tree leaf roller*, page 575.

6. Fruits of apple scarred by shallow feeding, most common where a leaf touches the fruit. Skin of the fruit is eaten. Injury occurs late in the season. *Red-banded leaf roller, Eulia velutinana* Walker (see *Penn. Agr. Exp. Sta. Bull.* 169, 1921; *Va. Agr. Exp. Sta. Bull.* 259, 1927).

7. Newly set apples with crescent-shaped punctures in the side of the fruit, often with a small hole cut on the inside of the apex of the crescent. Early-injured apples often containing small, white, fat-bodied, footless grubs. Small, round cavities or pits eaten in the surface of the apple from midsummer until midfall. Dark-brown snout beetles, about ⅙ inch in length, with grayish-white patches on the back and four slightly raised humps on the wing covers, feeding on the surface of the fruit. *Plum curculio*, page 577.

8. Injury similar to *E*, 7, but lacking the crescent-shaped cuts. The cavities are eaten deeper into the fruit, and are often close together, so that the side of the fruit may be peppered with small holes about ⅛ inch deep. Apples knotty, misshapen, and undersized. Dead areas of skin often present around the cavities. A brown to light-brown beetle, with slender snout one-half the length of the body, and with four very distinct humps on the wing covers, but lacking the white markings of *E*, 7, may be found feeding on the fruit. Injured fruit seldom drops unless heavily fed upon early in the season. *Apple curculio*, page 581.

9. Fruit with irregular russeted spots, misshapen, pitted, or dimpled in appearance, but without cavities and dwarfed in size; flesh often hard or woody under the injury. Elongate-oval, reddish bugs, about ¼ inch long, somewhat plump of body, with head

of orange color, feeding on the new foliage, and later on the fruit, by sucking the sap through their slender beaks. *Apple red bugs*, page 582.

10. Numerous, brown, twisting mines, containing yellowish-white maggots, up to ⅜ inch in length, run through the flesh of the fruit. These mines are most abundant in early varieties of apples, particularly in sweet apples. Mines in the fruit indicated by dark lines on the surface of the apple. Flies a little smaller than the house fly and of a general black color, marked with white bands on the abdomen and black bands on the wings, rest on the surface of the fruit, and deposit their eggs in the flesh. *Apple maggot*, page 584.

Flat-headed Apple-tree Borer[1]

Importance and Type of Injury.—The presence of this insect is indicated by shallow, broad, irregular mines or burrows on the main trunk or large branches, just under the bark and in the wood, the larger ones going into the wood a distance of an inch or two. Above these burrows are dark-colored, dead areas of bark. These burrows are packed tightly with fine sawdust except where they go into the wood; here they are usually packed with coarse, excelsior-like fibers. They are nearly always on the sunny side of the tree, but may extend completely around the tree. Injuries usually result in killing large areas of bark and sometimes in girdling and killing the tree or infested branches. There are several other closely related species that also sometimes attack apple.

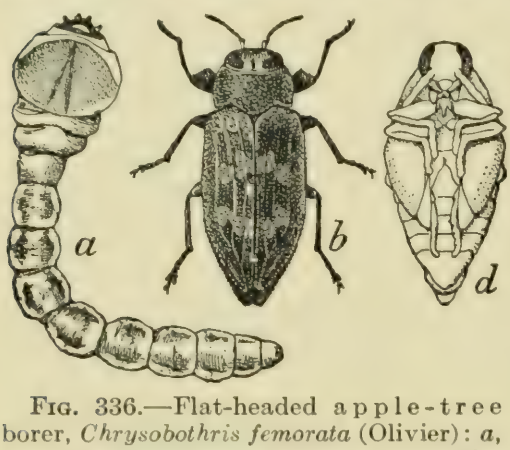


Fig. 336.—Flat-headed apple-tree borer, *Chrysobothris femorata* (Olivier): *a*, larva; *b*, adult beetle; *d*, pupa, about twice natural size. (*From Chittenden, U. S. D. A.*)

Trees Attacked.—Nearly all fruit, woodland, and shade trees.

Distribution.—Generally distributed throughout the United States and the fruit-growing sections of Canada.

Life History, Appearance, and Habits.—The winter is passed in the grub or borer stage. These are of different sizes, from ½ to a little over 1 inch in length. The larger, nearly full-grown borers will be found from 1 to 2 inches deep in the wood of the tree, usually to a less depth in the southern states. In the spring they change to yellow pupæ (Fig. 336, *d*) and later to beetles. The full-grown grub is about 1¼ inches in length, of a yellow to yellowish-white color with a broad flat enlargement of the body just back of the head (Fig. 336, *a*). It is this enlarged area which gives the insect its common name. The adult beetle (*b*) is about ½ inch long by ⅕ inch wide. It is of a dark olive-gray color with a metallic luster to the irregularly corrugated wing covers. The body is very blunt at the head, and tapers to a rounded

[1] *Chrysobothris femorata* (Olivier), Order Coleoptera, Family Buprestidæ.

point at the posterior end. They are decidedly sun-loving insects, and will be found in greatest numbers on the sunny sides of trees or logs. The female beetle lays her eggs in cracks in the bark of trees, nearly always selecting a tree that is unhealthy, or a spot on a healthy tree where the bark has been injured, as by sun scald or a bruise. The eggs are laid from May to August, and most of the borers complete their growth by fall, the life cycle occupying only 1 year.

Control Measures.—The only effective remedy, once a tree is infested, is to cut out the grubs with a sharp-pointed knife. This should be done during the late summer or early fall. The presence of the insects is indicated by darkened areas of bark and fine bits of sawdust protruding through the bark.

To prevent trees from becoming infested, they should be kept in good condition. The south sides should be shaded with a board or stake for the first 2 years after they are set. Wounds should be painted with a mixture of coal tar 75 per cent, and crude creosote 25 per cent.

The following wash is strongly recommended by the Michigan Experiment Station as a repellent to the adult beetles, to prevent egg laying:

Common potash laundry soap	50 pounds
Water	3 gallons
Flake naphthalene	25 pounds
Flour	2 pounds

Place the soap in the water in a warm place and allow it to soften for a few days. Use a potash soap which will form a smooth mixture, not a soda soap, since the latter becomes jelly-like. Then place water and soap in a double boiler (we use a medium-sized wash boiler placed inside a very large one) and cook until the temperature reaches 180° F. Stir in the flour and add the naphthalene and bring the temperature to 180° F., a temperature at which the naphthalene will have melted, the melting point of naphthalene being 176°, then cool as quickly as may be, stirring the mixture occasionally. The more rapidly the mixture is cooled, the smaller will be the crystals of naphthalene. The mixture should be applied with a brush while it is warm.

References.—U. S. Dept. Agr., Farmers' Bulls. 1065, 1919; and 1270, 1922.

Round-headed Apple-tree Borer[1]

Importance and Type of Injury.—The damage is all caused by the borer, or grub, which feeds on the inner bark and sapwood of the tree. The burrows of this insect are usually made in the base of the trunk, from 1 or 2 inches below the surface of the ground to a foot or more above ground. They extend through the sapwood and heartwood, often seriously weakening young trees; and sometimes girdle the tree. The

[1] *Saperda candida* Fabricius, Order Coleoptera, Family Cerambycidæ.

presence of the insect is indicated by coils or piles of sawdust-like particles adhering to the bark, or on the ground about the base of the trunk (Fig. 337), and by darkened areas in the bark about the base of the tree. To make a thorough examination for the presence of this insect, it is necessary to remove the earth about the base of the trunk to a depth of 2 or 3 inches and examine the bark carefully.

Trees Attacked.—Apple, pear, quince, haw, mountain ash, service-berry, and occasionally some others.

Distribution.—The eastern United States and Canada, also New Mexico and British Columbia.

Life History, Appearance, and Habits.—The winter is passed only in the larval or borer stage. The borers are of two sizes; those which have

FIG. 337.—Castings of round-headed apple-tree borer at base of apple tree. (*From U. S. D. A. Farmers' Bull.* 1270.)

FIG. 338.—Larva of round-headed apple-tree borer, nearly full grown. About natural size. (*From U. S. D. A. Farmers' Bull.* 1270.)

hatched from eggs laid the past season, and those from eggs laid a year earlier, the latter being full-grown and an inch or over in length. They are of a creamy-yellow color, with a brown head and a rounded thickening of the body just behind the head (Fig. 338). The two-year-old larvæ are usually found in the tree to a depth of 1 to 2 inches. In the spring of the year these larger larvæ change to the pupal stage and, after 2 weeks to a month's time, emerge as robust velvety brown cylindrical beetles with a conspicuous white stripe on each side of the body, above, and the under side of body, legs, and head, except the eyes, also white (Fig. 339). The beetles are quite striking in appearance. They are abroad from June to the first of September. The adults crawl over the surface of the tree and feed to some extent on the foliage and on the

new twig growth. They have well-developed wings, but are rather sluggish creatures and usually fly only short distances. They lay their eggs during the summer months, these being deposited in the bark of the trunks of apple trees from just below the surface of the ground to 18 or 20 inches up on the trunk, or occasionally even higher than this. They are usually laid in cracks of the bark, which are sometimes enlarged by the beetles with their strong jaws. The borers upon hatching feed at first on the outer bark, and as they increase in size, work into the wood of the tree. The older, or nearly full-grown ones, are found several inches within the wood, and are usually a foot or more above the surface of the ground, while the young borers may work several inches below the surface. When full-grown, the larva hollows out a cell in the wood in which to pupate. In most cases, the insect requires 2 years in which to complete its growth, but may require 3 under unfavorable conditions.

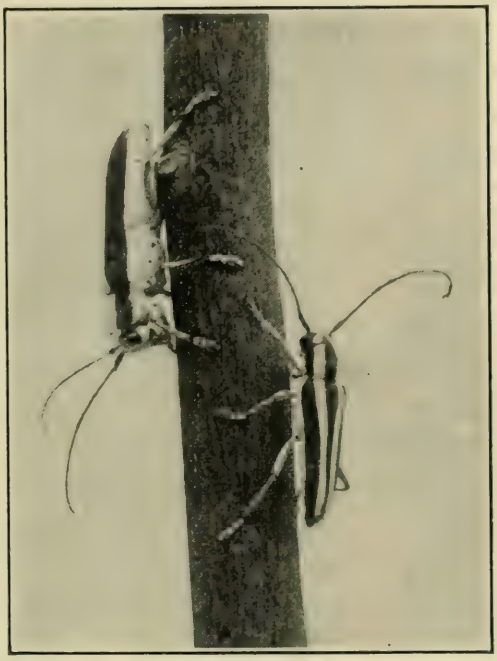


FIG. 339.—Adult male and female round-headed apple-tree borer, *Saperda candida* Fabricius. Male on right, female on left, about natural size. (*From U. S. D. A. Farmers' Bull.* 847.)

Control Measures.—Many paints and washes have been tried to prevent the adult borers from laying their eggs in the bark. None of these have proved very effective, although some have given fair results. The best control now known is to go over the trees twice each year, once during the latter part of August or early September, and again in late April. The spring examination may not be necessary except where borers are abundant. The base of the tree should be carefully examined, 1 or 2 inches of the soil around the trunk removed, and the young borers dug out or probed out. So far as possible, workmen should avoid cutting across the grain of the bark. A flexible wire is used to reach the borers deep in the wood. The ordinary spray schedule applied for controlling other orchard insects aids to some extent in controlling the round-headed apple-tree borer, as the adults will frequently get enough poison to kill them when feeding on the new bark or the leaves. All growth of crabs, haws, and particularly service-berry and mountain ash should be kept down within ¼ mile of the apple orchard.

References.—*U. S. Dept. Agr. Farmers' Bull.* 1270, 1922; *U. S. Dept. Agr. Dept. Bull.* 847, 1920.; *Ark. Agr. Exp. Sta. Bull.* 146, 1918.

Shot-hole Borer or Fruit-tree Bark Beetle[1]

Importance and Type of Injury.—Small holes, about the size of a pencil lead, in the bark of branches and trunks of trees, often enter the bark above a bud or other projection. The holes are sometimes indicated by a small amount of sawdust or borings on the bark of the tree. When the insects become very abundant, wilting and yellowing of the foliage occurs, and is usually followed by the death of the tree. Bark of infested trees is perforated with numerous small shot-hole-like openings, from which the beetle gets the name "shot-hole borer." The removal of the bark exposes many, small, winding, sawdust-filled, gradually-enlarging galleries leading out from a shorter central gallery (Fig. 340, *C*). In nearly all cases, the borers' attack results in the death of the tree or branches where they are numerous, but they are very rarely the *primary* cause of the death of the tree.

Trees Attacked.—Apple, peach, plum, cherry, quince, service-berry, choke cherry, and others.

Distribution.—This insect is a native of Europe, but is now generally distributed over the United States.

Life History, Appearance, and Habits.—During the winter, this insect is in the grub or larval stage in the inner bark. At this time, the grubs are about 1/8 inch long, of a pinkish-white color, with a slight enlargement of the body just behind the head (Fig. 340, *A*). In the early spring they change to the pupæ, and emerge as full-grown insects during June and July. The adult insect (*B*) is about 1/10 inch long, by half as wide, black in color, the body very blunt at either end. They have well developed wings and are capable of flying considerable distances. The insects mate, and females seek out trees that are in a somewhat unhealthy condition. They enter the bark at a point along the branch or twig, usually just above a slight projection, and excavate a gallery about 2 inches long usually running in the same direction as the length of the trunk or branch. They deposit their eggs at short intervals on either side of this parent gallery. The young grubs hatching from these eggs start burrowing in the inner bark, in general at a sharp angle from the parent gallery. They continue their burrows until they become full-grown, about 6 to 8 weeks. The larval burrows are from 2 to 4 inches long, enlarging slightly throughout their length and diverging gradually outward from the parent gallery. When full-grown, the larva changes to a pupa and later to an adult beetle at the end of the larval burrow beneath the bark. The beetles emerge from holes bored directly outward through the bark. There are from one to three generations of the insect each year, the larger number occurring in the South.

Control Measures.—Many experiments have been carried out to test the effect of treating the bark of infested trees with some substance

[1] *Scolytus rugulosus* Ratzeburg, Order Coleoptera, Family Scolytidæ.

strong enough to kill the young larvæ in their burrows. Some fairly favorable results have been obtained by using a solution of carbolineum. In many cases, however, severe injury to the trees has resulted from the use of this substance. Probably the best method of overcoming the attack of this insect is to stimulate the tree by the application of some strong nitrogenous fertilizer, such as nitrate of soda or sulphate of ammonia. Trees that are in a backward, somewhat sickly, condition in the spring should be given a heavy treatment with one of these ferti-

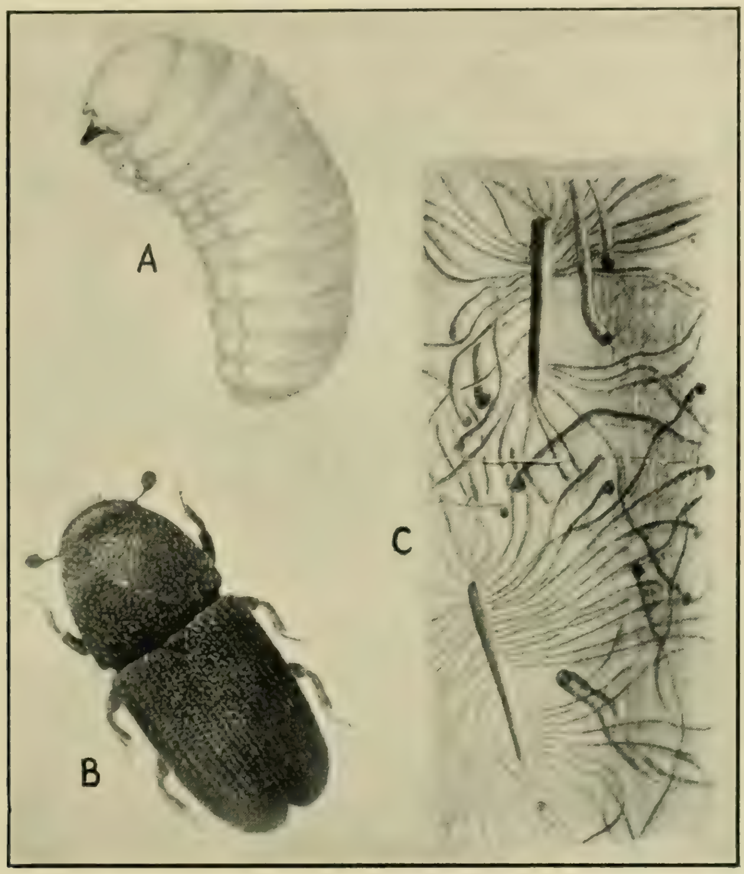


Fig. 340.—Shot-hole borer. *A*, larva or grub; *B*, adult or beetle, about fifteen times natural size; *C*, parent and larval galleries in sapwood of injured twig from which the bark has been removed; about natural size. (*From Ill. State Nat. Hist. Sur.*)

lizers, applying the material to the surface of the soil above the roots of the tree. The dosage should vary with the size of the tree. Ten-year-old trees may safely receive from 3 to 5 pounds of either of these fertilizers, and the amount may be doubled on twenty-year-old trees.

During the winter all badly diseased trees or branches in or near the orchard should be cut out and all prunings promptly removed and burned. This applies not only to the apple, but to the other favored food plants of this insect.

References.—*U. S. Dept. Agr. Farmers' Bull.* 1270, 1922; *Ohio Agr. Exp. Sta. Bull.* 264, 1913; *Report of State Entomol. of Neb.*, 1909.

Pin-hole Borers[1]

Importance and Type of Injury.—There are several species of small beetles somewhat resembling the bark beetles in appearance that attack the apple and many other trees. These insects bore directly into the wood of the tree, and live on a fungus which they grow in their burrows. They confine their work almost entirely to dead or dying trees.

Trees Attacked.—All the common fruit trees and most forest trees are subject to attack by these insects.

Distribution.—General over the United States.

Control Measures.—The control measures are the same as for the shot-hole borer.

Reference—Dom. Canada, Dept. Agr. Entomol. Branch, Bull. 14, 1918.

Fig. 341.—New York weevil, *Ithycerus noveboracensis* (Forster). Adults feeding on twig of apple and their characteristic injury. Natural size. (*From Ill. State Nat. Hist. Sur.*)

New York Weevil[2]

Importance and Type of Injury.—Large, black-mottled, grayish, snout beetles feeding on the buds and the young twigs of apple. The buds are often completely eaten out and the twigs gnawed and cut off (Fig. 341).

Trees Attacked.—Apple, peach, plum, pear, hickory, oak, cherry, and several others.

Distribution.—United States east of the Rocky Mountains. Most abundant in the Mississippi Valley and southern states.

Life History, Appearance, and Habits.—The life history of this insect has not been worked out in a detailed manner. The injury to apple is all caused by the feeding of the adults, which, so far as known, are the only stage found on that tree. In the

[1] *Monarthrum mali* Fitch and other species, Order Coleoptera, Family Scolytidæ.

[2] *Ithycerus noveboracensis* (Forster), Order Coleoptera, Family Belidæ.

East, the adult beetle is supposed to deposit its eggs in the small branches of hickory and oak trees. The grubs or larvæ hatching from these eggs are said to feed on the twigs of oak and hickory from June to the approach of cold weather, and remain dormant during the winter. They change to pupæ in the spring, and emerge as full-grown beetles during May. In west-central Illinois, the beetles are abundant on apple from about the first of May to the middle of June, and it is during this period that all damage to fruit trees is done. The adult insect is quite conspicuous because of its size, being nearly ¾ inch long, of a robust appearance, and one of the larger snout beetles.

Control Measures.—Hand picking is the only known means of preventing injury. Mature orchards are seldom, if ever, damaged; the injury occurs on young trees, so that hand picking may be considered a practical control measure. The injury is severe only in young orchards in cut-over land or near hickory or oak woodland.

Imbricated Snout Beetle[1]

Importance and Type of Injury.—Occasionally, buds of apple and newly forming fruits are injured by a grayish snout beetle, somewhat smaller than the New York

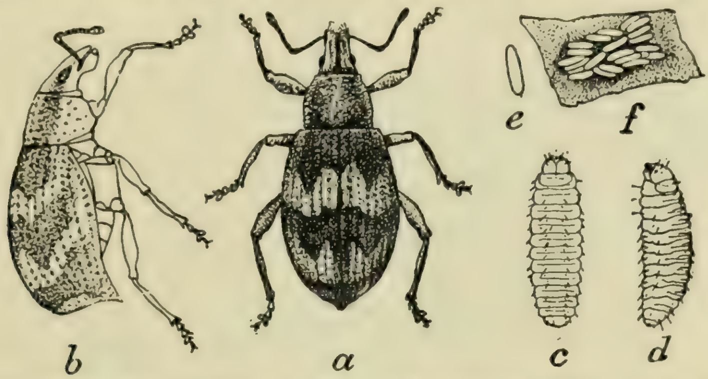


Fig. 342.—Imbricated snout beetle, *Epicærus imbricatus* Say. *a*, *b*, adult, dorsal and side views, three times natural size; *c*, *d*, larva, dorsal and side views, enlarged; *f*, eggs on leaf, twice natural size; *e*, egg more enlarged. (*From Ill. State Nat. Hist. Sur.*)

weevil. This insect has a body which is very plump and well rounded (Fig. 342, *a*, *b*). It injures the apple by eating out the buds, or cutting off the young fruit and leaves. It is a very general feeder, and is found on many other plants, causing great damage to strawberries. It has seldom been abundant enough to cause serious injury in well-cared-for orchards.

Life History, Appearance, and Habits.—The eggs of this insect (Fig. 342, *e*, *f*) are laid on the leaves of many plants, and the immature stages (*c*, *d*) are passed in the stems or on the roots of legumes or some other field crops The adult insects make their appearance on the trees during the latter part of May and June, and continue feeding for about one month. There is one generation a year.

Control Measures.—If the beetles are causing damage to young trees, many of them may be caught by jarring them on to sheets spread under the trees. A strong arsenate of lead spray, used at the rate of 3 pounds of powder to 50 gallons of water, will kill many of the insects.

Periodical Cicada or Seventeen-year Locust[2]

This insect (Figs. 345 and 346) is so well known that a description is hardly needed. The body is wedge-shaped, nearly black and from

[1] *Epicærus imbricatus* Say, Order Coleoptera, Family Curculionidæ.

[2] *Magicicada septendecim* (Linné), Order Homoptera, Family Cicadidæ.

1 inch to $1\frac{1}{2}$ inches long, including the wings. It is, however, frequently confused with the common "harvestman" or dog-day cicada.[1] There are two races of the periodical cicada which cause damage to fruit trees. One of these has a life cycle of 13 years, and is abundant only in the southeastern part of the United States (Fig. 343). The other race, which is the true seventeen-year cicada, or seventeen-year "locust," is more abundant in the northeastern part of the United States and has a 17-year life cycle (Fig. 344). There are a number of broods which overlap, the adults appearing in different years. Adults of both races

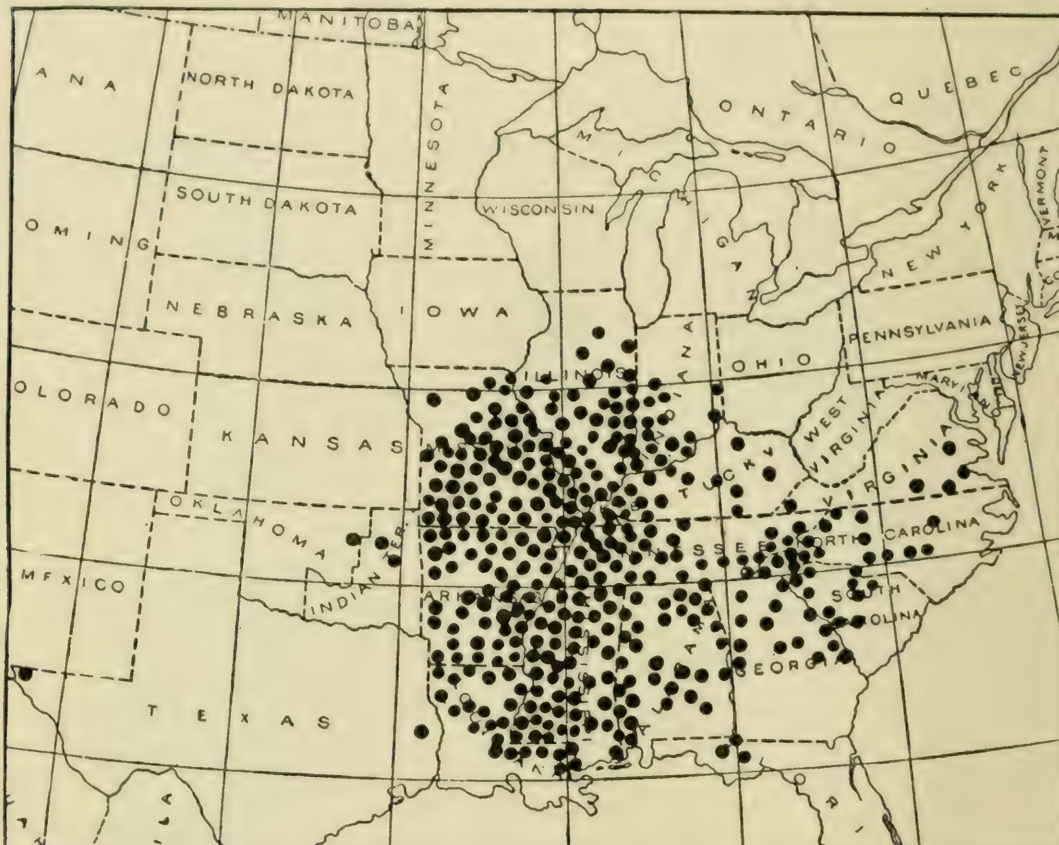


FIG. 343.—Periodical cicada. Map showing distribution of the combined broods of the 13-year race. (*From U. S. D. A. Bureau of Entom., Bull.* 71.)

are smaller than the dog-day cicada, and appear during May, June, and very early July, while the dog-day cicada is present every year during July, August, and September. The dog-day cicada never causes noticeable injury. In both races of the periodical cicada, the margins of the wings have a distinct reddish tinge and a black "W" is present near the lower margin of the front wing. The dog-day cicada is much larger, has a greenish margin to the wings, and lacks the black "W" of the thirteen- and seventeen-year species.

[1] *Tibicen linnei* (Smith and Grossbeck), and other species, Order Homoptera, Family Cicadidæ.

Importance and Type of Injury.—Roughened punctures in the twigs and small branches of apple and many other trees, usually from 1 to 4 inches in length. The bark is pushed from the wood and the wood of the twig cut and raised so that a series of small bundles of splinters protrude from the surface (Fig. 5, *A*). This injury is caused not by the feeding of the insect, but by the female cicada's depositing her eggs in the twigs (Fig. 346).

Distribution.—The thirteen-year form ranges from Virginia and southern Iowa and Oklahoma on the north and west, to the Atlantic

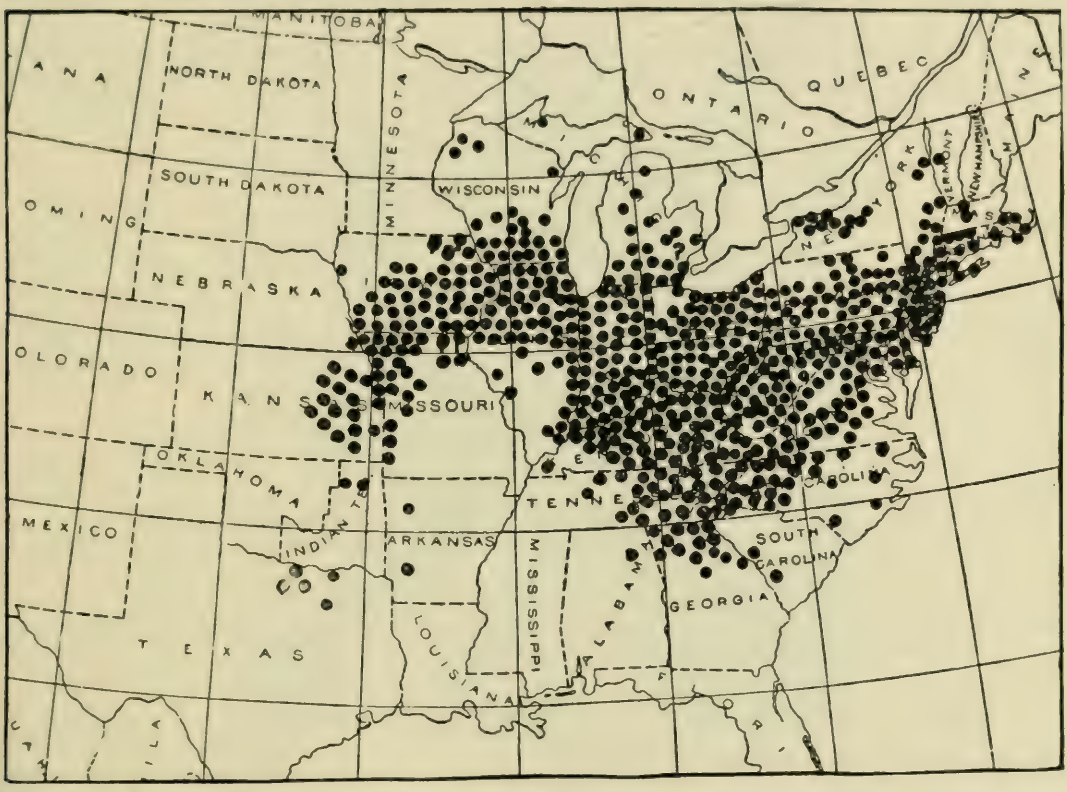


FIG. 344.—Periodical cicada. Map showing distribution of the combined broods of the 17-year race. (*From U. S. D. A. Bureau of Entom. Bull.* 71.)

Coast and Gulf of Mexico. The seventeen-year form ranges from Vermont, Massachusetts, Michigan, and Wisconsin on the north, Colorado on the west, to Texas, northern Alabama, and northern Georgia on the south. Both are most abundant east of the Mississippi River. This insect is not known to occur outside of eastern North America.

Life History, Appearance, and Habits.—This species has the longest developmental period of any known insect. The eggs are laid during late May, June, and early July, in the above-described punctures, in the twigs and small branches of trees. The females lay from 400 to 600 eggs, depositing from 12 to 20 in each puncture beneath the bark. Many egg punctures may occur in a single line, as many as 50 having been found along one branch. The eggs hatch in about 6 or 7 weeks (see Figs. 77, *F* to *J*). The somewhat ant-like young drop to the ground and enter the soil

through cracks, or at the base of plants. Here they excavate a small cell about a tree rootlet from which they suck the sap. They grow very slowly and their feeding usually has no noticeable effect on the trees, on the roots of which thousands of the young cicadas occur. After 13 or 17 years of this underground existence, the nymphs have become full-grown. The insects are now about an inch in length and somewhat resemble a small crayfish (Fig. 79, *L*). The full-grown nymphs burrow to the surface of the soil and emerge through small holes about ½ inch in diameter. They sometimes construct mud cones or "chimneys" about these holes to a height of 2 to 3 inches, with the opening near the ground. They appear in large numbers at about the same time, emergence usually starting soon after sunset. They crawl upon the trunk of some tree or

Fig. 345.—Adult periodical cicada beginning to issue from nymphal shell. About natural size. (*From U. S. D. A. Bureau of Entom., Bull.* 71.)

the stem of a weed, which they grasp firmly. The skin splits down the middle of the back and the adult insect gradually works its way out (Fig. 345). They remain on the support until their wings harden and the bodies dry, but by the following day they are ready to take flight, the empty skins often remaining clinging to tree trunks and other supports for months. As many as 20,000 to 40,000 may emerge from the ground under one large tree. They fly about during the day, mate, and feed by sucking the sap from the twigs of trees. The injury caused in this way is very slight. Four or five days after emergence the males start "singing." This song is a very high-pitched, shrill call, produced by two drum-like membranes on the sides of the first abdominal segment. The adults live from 30 to 40 days.

Control Measures.—No spray or dust has been found which can be applied to the trees that will prevent the egg laying of the female cicadas. Young trees or particularly valuable fruit trees, may be covered with mosquito bar or other cheap cloth, during the period when the adult cicadas are on the wing. Orchards set on soil where trees were standing

during the last appearance of the adults, will be more heavily infested than those set on prairie soil, or at some distance from woodland. Young fruit trees should not be heavily pruned the winter or spring before the

FIG. 346.—Periodical cicada. Female depositing eggs in apple tree and characteristic egg-punctures. (*From Wellhouse, "How Insects Live," after Snodgrass. Copyright*, 1926, *by the Macmillan Company. Reprinted by permission.*)

appearance of the adult cicadas. After the cicadas have disappeared, the seriously weakened twigs should be pruned off and burned.

References.—U. S. Dept. Agr. Bureau Entomol. Bull. 71, 1907; *Ohio Agr. Exp. Sta. Bull.* 311, 1917; *Ohio Agr. Exp. Sta. Circ.* 142, 1914; *Mo. Agr. Exp. Sta. Bull.* 137, 1915.

BUFFALO TREEHOPPER[1]

Importance and Type of Injury.—Double rows of curved slits are cut in the bark of small branches and twigs. If these slits (Figs. 347, and 5, *c*) are carefully cut open, a row of from 6 to 12 small, elongated, yellowish eggs will be found embedded in the inner bark just under each slit. The bark of infested trees presents a roughened, somewhat scaly appearance and never makes a very vigorous growth.

[1] *Ceresa bubalus* (Fabricius), Order Homoptera, Family Membracidæ.

Plants Attacked.—Apple, quince, cherry, prune, elm, locust, cottonwood, and many other trees. The nymphs feed on weeds and grasses.

Distribution.—General throughout the United States and southern Canada.

FIG. 347.—Twigs of apple showing injury by the egg punctures of the buffalo treehopper, slightly enlarged. (*From Ill. State Nat. Hist. Sur.*)

Life History, Appearance, and Habits.—The insect remains in the egg stage during the winter, hatching rather late in the spring into a tiny, pale-green, spiny nymph (Fig. 79, *B*), which feeds on the sap of various

FIG. 348.—Buffalo treehopper, adults in dorsal and side views about six times natural size. (*From Ill. State Nat. Hist. Sur.*)

grasses and weeds, reaching its full-grown stage during August. The new adults then deposit their eggs in the bark for the next year's generation, after which the adults die. The full-grown buffalo treehopper (Fig. 348) is a peculiar shaped little insect of a light-green color, triangular in outline,

very blunt at the head end with a short horn at each upper corner, and pointed behind. They are about 1/4 inch long by two-thirds as wide at the head end. The female treehopper has a very sharp, knife-like ovipositor with which she cuts the slits in the twigs and through these forces her eggs into the inner bark.

Several other species of treehoppers attack apple and other fruit trees, most of them having practically the same life history as that of the buffalo treehopper. Some species differ in their manner of laying eggs, and cut a single row of slits in the bark of the tree; others lay their eggs in gummy covered masses on the surface of the bark.

Control Measures.—The best method of controlling this insect is clean cultivation of the orchard, keeping down all weeds or grassy growth. When the insect is abundant, the growing of summer cover crops, such as clover or cowpeas, should be discontinued for one or two seasons, and the orchard kept clean of all vegetation until the latter part of July. Spraying is not effective in controlling this pest.

References.—U. S. Dept. Agr. Farmers' Bull. 1270, 1922; *N. Y. (Geneva) Agr. Exp. Sta. Tech. Bull.* 17, 1907.

San José Scale[1]

Importance and Type of Injury.—Trees lightly infested show small grayish specks on the surface of the bark which are disc-shaped, and just discernible to the eye (Fig. 349). Under the hand lens, these specks show a raised, nipple-shaped spot at the center. Frequently the bark is reddened for a short distance around each of the scales, this being especially true on young trees and on new growth of old trees. On heavily infested trees the entire surface of the bark is covered with a gray layer of overlapping scales, appearing as if the twig or branch had been sprinkled with wood ashes when wet. Infested trees show a general decrease in vigor, and thin foliage, which is usually more or less yellowed and spotted because of the presence of scales upon it. Sometimes there is an abundance of water sprouts along the larger branches. The fruit on infested trees is also attacked by the scale, the insects being most abundant around the blossom and stem ends, often forming a gray patch about the calyx of the apple. The fruit on infested trees often has a spotted or mottled appearance because of a small red inflamed area surrounding each of the scales (Fig. 63, *E*). If allowed to develop unchecked, the infestation in most cases results in the death of the tree. In 1922, more than 1,000 acres of mature apple trees were killed in southern Illinois by this insect.

Trees Attacked.—Apple, pear, quince, peach, plum, prune, apricot, nectarine, sweet cherry, currant, gooseberry, and osage orange, besides many bush fruits and shrubs and some shade and forest trees.

[1] *Aspidiotus perniciosus* Comstock, Order Homoptera, Family Coccidæ.

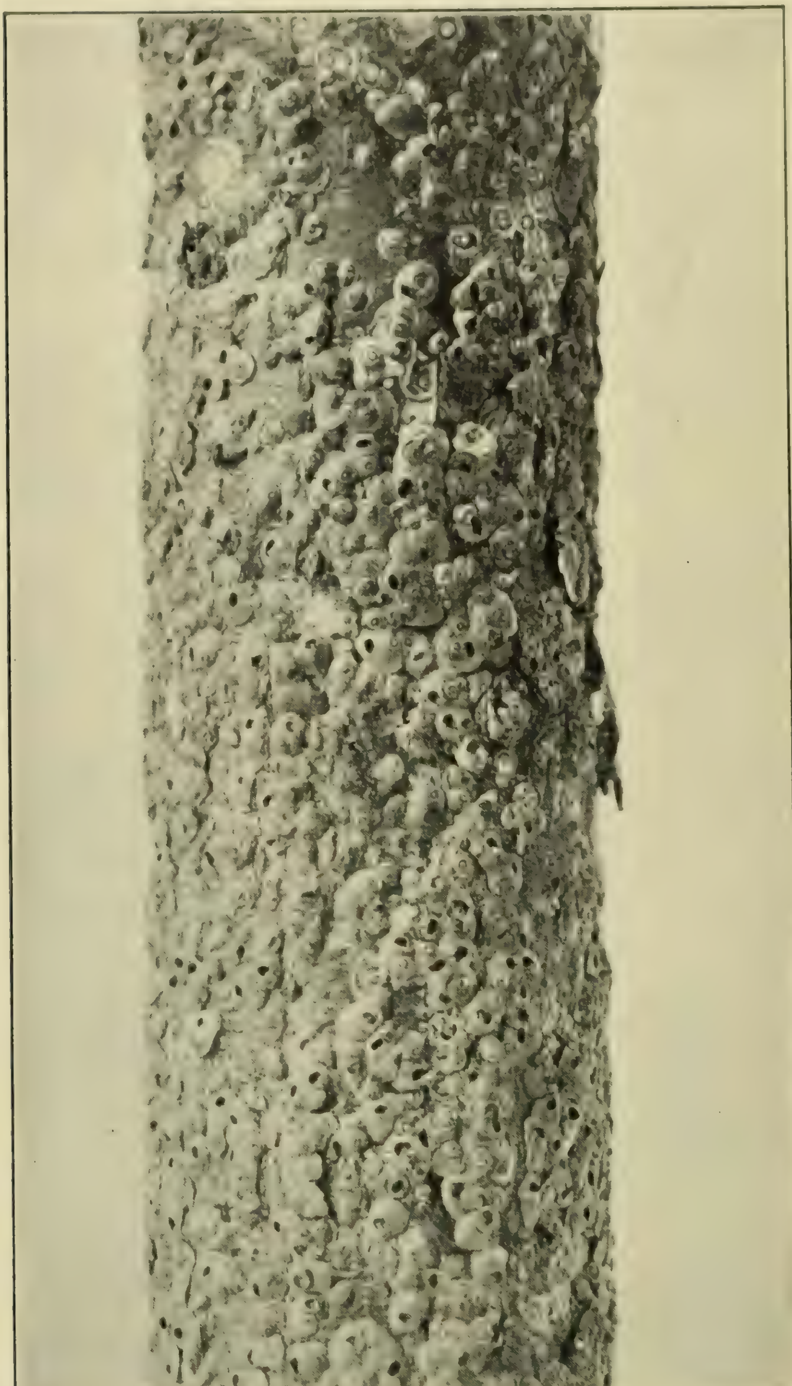


FIG. 349.—Twig of apple encrusted with San José scale, *Aspidiotus perniciosus* Comstock. Many of the scales show exit holes of a hymenopterous parasite. Both male and female scales can be recognized. Enlarged several times. (*From Ill. State Nat. Hist. Sur.*)

Distribution.—Throughout the commercial fruit-growing sections of the United States and Canada and in many other parts of the world.

Life History, Appearance, and Habits.—The insect passes the winter in a partly grown condition. Nearly all the scales surviving a temperature of 10° F. above zero, are in the second nymphal instar, often known as the sooty-black stage, and are about one-third grown. The insect remains dormant, tightly fastened to the bark of the tree until the sap starts flowing in the spring. It then begins to grow, and usually becomes full-grown about the time the apple trees come into bloom. At this time two forms of scales will be noted, one nearly round about $\frac{1}{12}$ inch across, with a raised nipple in the center, and the other oval, about $\frac{1}{25}$ inch long by half as broad, with a raised dot nearer the larger end of the scale. The latter scales are the waxy covering of the males, which emerge as small, yellow, two-winged insects (Fig. 350) at about this time. The larger, round scales cover the bodies of the females, which remain under the scales throughout their lives, and, after mating, begin to give birth to living young. They continue to reproduce for a month or more, depending on the temperature. These young have the appearance of very small, yellow mites or lice (Fig. 63, *F*). They have six well-developed legs, and two antennæ, and crawl about over the surface of the bark for a short time. On finding a place which is attractive to them, they insert their slender, thread-like mouth parts through the bark and begin sucking the sap. Very shortly after this they molt or shed their skins and with the old skin lose their legs and feelers, becoming mere flattened yellow sacks attached to the bark of the tree by their sucking mouth parts. As the insect grows, a waxy secretion is given off from the body and this hardens into the protective scale under which the insect lives. There are from two to possibly six generations of the scale each year; the smaller number occurring in the northern part of the country, and the larger in the extreme southern. The insect increases most rapidly in dry, hot seasons, it having been determined that the progeny of a single female insect could be well over 30,000,000 in a single year.

FIG. 350.—San José scale, adult male greatly enlarged. (*From Ill. State Nat. Hist. Sur.*)

The insect is carried accidently from orchard to orchard on the bodies of birds and larger insects, and also to a greater extent by being blown through the air by the wind. It has been spread throughout the entire country on shipments of infested nursery stock, the original infestation in this country having been started from an importation of Chinese plants

which were set out on the grounds of a large estate at San José, California, about 1870; and from that city the scale gets the name by which it is known in North America.

Control Measures.—The best method of controlling this insect is by the use of a dormant spray which will kill the insect by the action of the spray on its body. From the time of the general spread of the scale in the east, about 1905, up to 1921, lime-sulfur was the material generally used for this purpose.

The years 1917 to 1923, were extremely favorable to the San José scale in Arkansas and Illinois, and in many orchards the lime-sulfur solution did not give a satisfactory control. More effective, and also less expensive, sprays are the so-called lubricating oil emulsions (see p. 250). For moderate infestations of scale, 1½ gallons of a 66⅔ per cent stock emulsion should be mixed in 50 gallons of water, applying the spray during the dormant stage of the trees. For severe infestations, 2 gallons of the stock emulsion should be used in 50 gallons of water. This spray should not be used in tanks that have contained lime-sulfur solution, without a thorough cleaning. With severe infestations of San José scale, this spray has been found superior to lime-sulfur, and the most effective control. Lime-sulfur is effective in the cooler parts of the country. It should be used at a dilution of 1 part to 7 or 8 parts of water where the concentrated lime-sulfur solution tests 33° Bé. (see Table XI, p. 249). There are also a number of commercial oil sprays that have given excellent control of San José scale when properly used.

Fall spraying with lime-sulfur may be practiced where for any reason it is not easy to spray in the spring, but the results obtained have not been quite as good as those from the spring applications. With the oil sprays, the application may be made at any time when the tree is in a dormant condition and the temperature is above freezing. In some of the western states, damage to the trees has resulted where oils have been used just before a drop in temperature to 20° F. below zero or lower. The spring applications are most effective, if made just before the leaves appear on the trees.

In order to control San José scale, it is necessary to do the most thorough and careful spraying. Bear in mind when spraying, that only those insects which are actually hit by the spray will be killed, that the insect to be hit varies from the size of a pencil point to that of a pinhead, and that they are generally distributed all over the bark of the tree on the twigs, branches, and trunk.

References.—*Ill. Agr. Exp. Sta. Circ.* 180, 1915; *Bull. Ill. State Nat. Hist. Survey*, Vol. 17, Art. V, 1928; *U. S. Dept. Agr. Farmers' Bull.* 650, 1915; *U. S. Dept. Agr. Bur. Entomol. Bull.* 62, 1906. Experiment Station publications of nearly all fruit-growing states.

Scurfy Scale[1]

Importance and Type of Injury.—This insect is found on the bark of the tree in the form of a grayish-white scale, about ⅛ inch long, rounded at one end and tapering to a rather sharp point at the other (Fig. 351). Scales are usually more abundant on the shaded parts of the tree and in orchards where trees have not been properly pruned or the foliage is too dense. The injury is much the same as that caused by the San José scale, but not nearly so severe. The fruit is sometimes spotted by this insect.

Plants Attacked.—Pear, apple, gooseberry, currant, black raspberry, Japan quince, mountain ash, and other common deciduous trees and bush fruits.

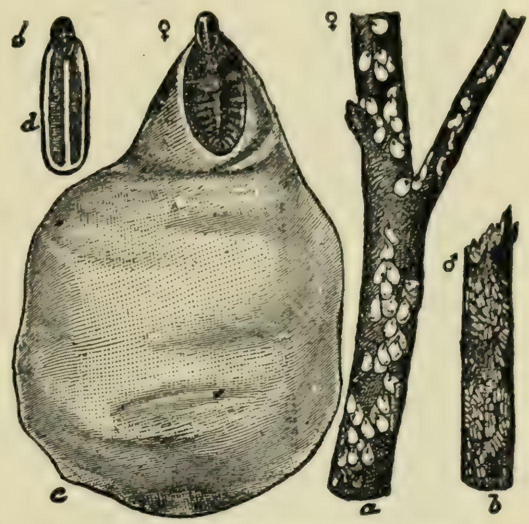


Fig. 351.—Scurfy scale, *Chionaspis furfura* Fitch. *a*, female scales on twig, natural size; *b*, male scales on twig natural size; *c*, female scale about twenty times natural size; *d*, male scale about twenty times natural size. (*From U. S. D. A.*)

Distribution.—This is a native insect which is found in the United States, from Idaho and Utah eastward.

Life History, Appearance, and Habits.—The scurfy scale passes the winter as reddish-purple eggs under the female scale. The eggs hatch rather late in the spring after the apple trees have come into full leaf. The minute, purplish, young nymphs crawl about for a few hours and then settle down on the bark for the remainder of their lives. The female scales are, when full-grown, about ⅛ inch in length, the males are only about one-fourth as long, and are covered by a narrow, straight-sided, white scale with three distinct ridges along the back of it. From these scales the minute, two-winged males emerge and fly about to seek the females. The males die soon after mating and the females after they have laid their eggs. There are two generations of the insect each year throughout most of the country, but only one generation occurs in the North.

Control Measures.—The control measures given for the San José scale will be found effective for this insect, the lime-sulfur spray being entirely satisfactory.

References.—Slingerland and Crosby, "Manual of Fruit Insects," pp. 176–178, 1915; *Ohio Agr. Exp. Sta. Circ.* 143, 1914.

[1] *Chionaspis furfura* Fitch, Order Homoptera, Family Coccidæ.

Apple Oyster-shell Scale[1]

Importance and Type of Injury.—Small, dark-brown scales are found adhering closely to the bark of the tree, appearing very much like half of a minute oyster shell (Fig. 352). The scales are about ⅛ inch long by one-third as wide. They usually are more or less clustered on the bark and a heavily infested tree may have the bark entirely covered. The bark of the injured tree usually becomes cracked and scaly. The trees lose vigor, the foliage is undersized and specked with yellow, and in severe infestations the death of the tree results.

Fig. 352.—Twig infested with apple oyster-shell scale, *Lepidosaphes ulmi* Linné; about three times natural size. (*From Ill. State Nat. Hist. Sur.*)

Plants Attacked.—Apple, pear, mountain ash, quince, plum, raspberry, currant. A very closely related species, but not the same, has, during the past few years, become very destructive to shade trees (see p. 675). That species has only one generation, and does not attack the apple or other fruit trees.

Distribution.—This scale is largely confined to the northern two-thirds of the United States and southern Canada.

Life History, Appearance, and Habits.—The insect passes the winter in the form of grayish-white minute eggs tightly enclosed under the wax of the parent scale. From 40 to 60 or more of these eggs will be found under each female scale. The eggs hatch late in the spring after the apple trees have bloomed. The young nymphs, which are very small and whitish in color, crawl about over the bark for from a few hours to 1 or 2 days. Once having inserted their beaks into the bark, they begin the formation of a waxy scale coating which covers their bodies, and soon shed their skins and their antennæ and legs along with them. The scale is white at first, but later changes to polished brown. The insects become full-grown about the middle of July; the males then emerge as winged insects, and the females, after mating, deposit their eggs under their scales, the body gradually shrinking toward the pointed end of the scale as the eggs are deposited. The females die shortly after the last eggs are laid. These eggs hatch in about 2 weeks, and the second generation of scales becomes full grown during the early fall, there being two generations of this insect each season over much of its range. In the northern part of its range, probably only one generation occurs.

[1] *Lepidosaphes ulmi* Linné, Order Homoptera, Family Coccidæ.

Control Measures.—The oyster-shell scale does not yield readily to dormant treatments of oil emulsion or lime-sulfur, and where infestations are very severe, a summer spray with oil or lime-sulfur may be necessary. Dormant sprays of lime-sulfur, applied in the same manner and at the same strength as for the San José scale, will control all but the heaviest infestations, especially if followed by the usual summer sprays of lime-sulphur, 1 to 50 (see Spray Schedule, p. 586). Where serious infestations occur, a 2 per cent refined oil emulsion applied just at the time that the young scales are hatching and crawling about over the bark, unprotected by their waxy covering, is very effective. No fixed date can be given for applying this spray, and it will be necessary in order to accomplish the best results to watch the trees carefully and spray as soon as the crawling young appear in numbers. In the latitude of central Illinois, hatching occurs about the first of June.

References.—Ohio Agr. Exp. Sta. Circ. 143, 1914; *U. S. Dept. Agr. Farmers' Bull.* 1270, 1922.

Apple Aphids

Importance and Type of Injury.—Aphids of three different species are common on the foliage, fruit, and twigs of apple trees throughout the country. These are known as the rosy apple aphid, the green apple aphid and the apple-grain aphid. The last named is of little importance, although usually the most abundant early in the season. The relative abundance varies greatly with different seasons, sometimes one species being extremely abundant and the others scarce, while in other years all three may be very numerous. In many years the injury from aphids is slight. When they are abundant their feeding causes the leaves to curl and the stems and twigs to become stunted and unhealthy in appearance. The new twig growth sometimes assumes a curled and twisted appearance, even forming a loop. In many cases, particularly when attacked by the green and rosy aphids, the apples remain very small. Many of these fruits are also somewhat misshapen, hard and knotty in texture, and characteristically puckered around the calyx end (Fig. 354). The rosy apple aphid is the most injurious species of aphid occurring on the foliage of the apple. A fourth species, the woolly apple aphid, does not injure the fruits, but is common on trunks, branches, and roots.

Rosy Apple Aphid[1]

Plants Attacked.—Apple is the favorite host, although the insect feeds also on pear, thorn, and *Sorbus* and, during the summer, on the narrow-leaved plantain.

[1] *Anuraphis roseus* Baker, Order Homoptera, Family Aphididæ.

Distribution.—General throughout the United States and apple-growing sections of Canada.

Life History, Appearance, and Habits.—The dark-green, shiny, ovate eggs, in which stage the insect passes the winter, are attached to the bark of the twigs and branches and usually hidden away in crevices in the bark or the depressions and wrinkles formed around the buds, twigs, and old

FIG. 353.—Eggs of the three common species of apple aphids, enlarged. (*From N. Y. (Cornell) Agr. Exp. Sta. Memoir* 24, *June,* 1919.)

wounds (Fig. 353). The eggs begin to hatch when the buds start opening in the spring. With this species, the eggs do not all hatch at once, but continue for 2 weeks or sometimes longer. The young aphids (Fig. 355) make their way to the newly opening buds and feed on the outside of the leaf-bud and fruit-bud clusters, until the leaves have begun to unfold. They then work their way down the inside of the clusters and begin suck-

ing the sap from the stems and newly formed fruits. Their feeding causes the leaves to curl, and this affords the aphids protection from some of their natural enemies and from sprays or dusts applied to the tree for their control. The aphids which hatch from the eggs are all females, and are called the stem-mothers, as they are the mothers of the season's

FIG. 354.—Apples injured by rosy apple aphid. (*From N. Y. (Cornell) Agr. Exp. Sta. Memoir* 24, *June,* 1919.)

brood. In about 2 weeks or a little longer, depending on the weather, these stem-mothers, without mating, begin giving birth to young, and these young in turn begin reproducing in about 2 weeks. The body of the aphid has a somewhat waxy coating and usually a slight purplish or rosy tinge. They continue on the apple during May, and in smaller numbers through June and July. During the early summer, they migrate to stems and stalks of the narrow-leaved plantain, where they feed and

reproduce until fall. In the fall, winged ovoviviparous females fly back to apple trees and give birth to the true egg-laying females. The males develop a little later and fly to mate with the true females, which then deposit their eggs in the situations above mentioned. The eggs hatch the following spring.

Control Measures.—The most effective method of controlling this aphid is to spray with a strong contact insecticide applied when the leaf buds are showing tip green, and before the leaves have reached a sufficient size to afford shelter for the newly hatched aphids. Three per cent lubricating-oil emulsion will give a fair kill of these aphids, but not enough for satisfactory control in years when they are abundant. A 2 per cent oil emulsion with 40 per cent nicotine sulfate, at 1 part to 2,000, has given

Fig. 355.—Newly hatched nymphs of the three common apple aphids. 1, the green apple aphid; 2, the rosy apple aphid; and 3, the apple-grain aphid, much enlarged. (*From N. Y. (Geneva) Agr. Exp. Sta. Bull.* 431.)

very satisfactory results. Apparently all aphids are killed which are thoroughly wet with nicotine sulfate used at the rate of 1 part to 800, in lime-sulfur solution, or in water with 1 pound of potash soap to each 25 gallons. After the leaves are about half grown, nicotine dusts (see p. 241) have given better results than sprays.

It is only during an occasional season that these insects become destructively abundant. They are preyed upon by many natural enemies, including the lady beetles, syrphid flies, and aphid lions. In seasons when the spring is warm, the natural enemies usually become sufficiently abundant to control the aphids, and it is rarely necessary in such years to resort to artificial measures of control. When the spring is cold and backward, the aphids usually increase more rapidly than their enemies, and it is in such seasons that the greatest damage occurs.

References.—*Me. Agr. Exp. Sta. Bull.* 233, 1914; *N. Y. (Cornell) Agr. Exp. Sta. Mem.* 24, 1919; *N. Y. (Geneva) Agr. Exp. Sta. Bulls.* 415, 1916; 431, 1917; and 461, 1919; *U. S. Dept. Agr. Farmers' Bull.* 1128, 1920.

Green Apple Aphid[1]

The green apple aphid has much the same life history as the rosy apple aphid. It passes the winter in the same manner in the egg stage on the bark of the trees. Unlike the rosy aphid, it remains on the apple trees during the entire summer. It is difficult for the orchardist to distinguish the nymphs and eggs of this species from those of the rosy aphid and apple-grain aphid (see Figs. 353, 355).

Trees Attacked.—Apple, pear, wild crab, hawthorn, and possibly others.

Distribution.—General in the apple-growing sections of North America.

Control Measures.—The control measures are the same as for the rosy aphid, but somewhat more effective because of the fact that the eggs of this species nearly all hatch within a few days and the young will all be clustered on the buds at the time when the most effective spraying can be done. Since the green apple aphid remains on the apple during the summer, and there may be some migration from one orchard to another, a summer application of nicotine may be necessary. This species is also subject to wide fluctuations in abundance, being controlled by the same natural enemies as those attacking the more injurious rosy aphid.

References.—See under Rosy Apple Aphid.

Apple-grain Aphid[2]

This aphid spends practically its entire feeding period on various grains and grasses, being particularly abundant on the small grains commonly grown in the United States. It is of very little importance as an apple pest, as it does not remain on the apple tree long enough to cause serious deforming of the fruit, twigs, or foliage. Its eggs are laid on the apple twigs and cannot readily be distinguished from the two species previously discussed. In some states its eggs are by far the most abundant of the species found on apple, and for this reason, one cannot tell from the number of aphid eggs found on twigs during the winter, whether or not serious injury from these insects is likely to occur the following spring. The appearance of great numbers of these aphids on the buds in early spring may cause alarm, but they soon disappear from the apple.

Plants Attacked.—Apple, pear, wild crabs, and haws; and grains and grasses during the summer.

Distribution.—General throughout the country.

Control Measures.—No control measures are necessary for this species on apple.

References.—See under Rosy Apple Aphid.

[1] *Aphis pomi* De Geer, Order Homoptera, Family Aphididæ.

[2] *Rhopalosiphum prunifoliæ* (Fitch), Order Homoptera, Family Aphididæ.

Woolly Apple Aphid[1]

Importance and Type of Injury.—White cottony masses covering purplish aphids, clustered in wounds on the trunk and branches of apple, quince, elm, pear, and mountain ash, or on large knots on the roots and underground parts of the trunk (Fig. 356). Infested trees often with many short fibrous roots. These injuries sometimes cause the death of the tree, stunting, or serious retardation of growth. The injury on elm causes the formation of close clusters of stunted leaves at the tips of the twigs, the leaves being lined with purplish masses of aphids.

Trees Attacked.—Apple, pear, hawthorn, mountain ash, elm.

Distribution.—World-wide.

Life History, Appearance, and Habits.—In the North the winter is passed in the two forms, the eggs, and the immature nymphs. The eggs are normally deposited in cracks or protected places on the bark of the elm. The nymphs hibernate under ground on the roots of apple. In the warmer parts of the country, the egg-laying females may winter over on apple trunks and branches. The eggs hatch early in the spring. The aphids that emerge from these eggs are wingless and feed on the elm buds and leaves for two generations. They then produce a winged form which migrates to the apple, hawthorn, and mountain ash. They feed to some extent in wounds on the trunk and branches, and many work their way down the trunk below the surface of the ground. Their most severe injury is caused by feeding on the roots. During the summer the aphids reproduce by giving birth to living young. In the fall the wingless males appear and mate with wingless females, each female laying a single egg in the situations above described. Some winged females are present during the entire summer. The body of this aphid is really of a reddish or purplish color, but is nearly hidden under masses of bluish-white cottony wax that is exuded by the insect.

Control Measures.—The forms living on the trunk and branches of the tree may be killed by thorough spraying with the spray solutions already recommended for the green and rosy apple aphids. The spray will have to be applied with strong pressure in order to hit the bodies of the aphids, which are well protected by their waxy covering. The root-infesting forms may be killed on nursery stock by dipping the roots in a strong nicotine solution. Various methods of soil fumigation and applications of liquids have been tried against these insects, but up to the present time without much success. Cultivation and fertilization that will keep the trees in a vigorous growing condition will help in lessening the damage by these insects. One should be careful to avoid setting out infested trees.

References.—*U. S. Dept Agr. Office* of *Secretary, Rept.* 101, 1915; *U. S. Dept. Agr. Farmers' Bull.* 1270, 1922; *Me. Agr. Exp. Sta. Bulls.* 217 and 220, 1913, and 256, 1916.

[1] *Eriosoma lanigerum* (Hausman), Order Homoptera, Family Aphididæ.

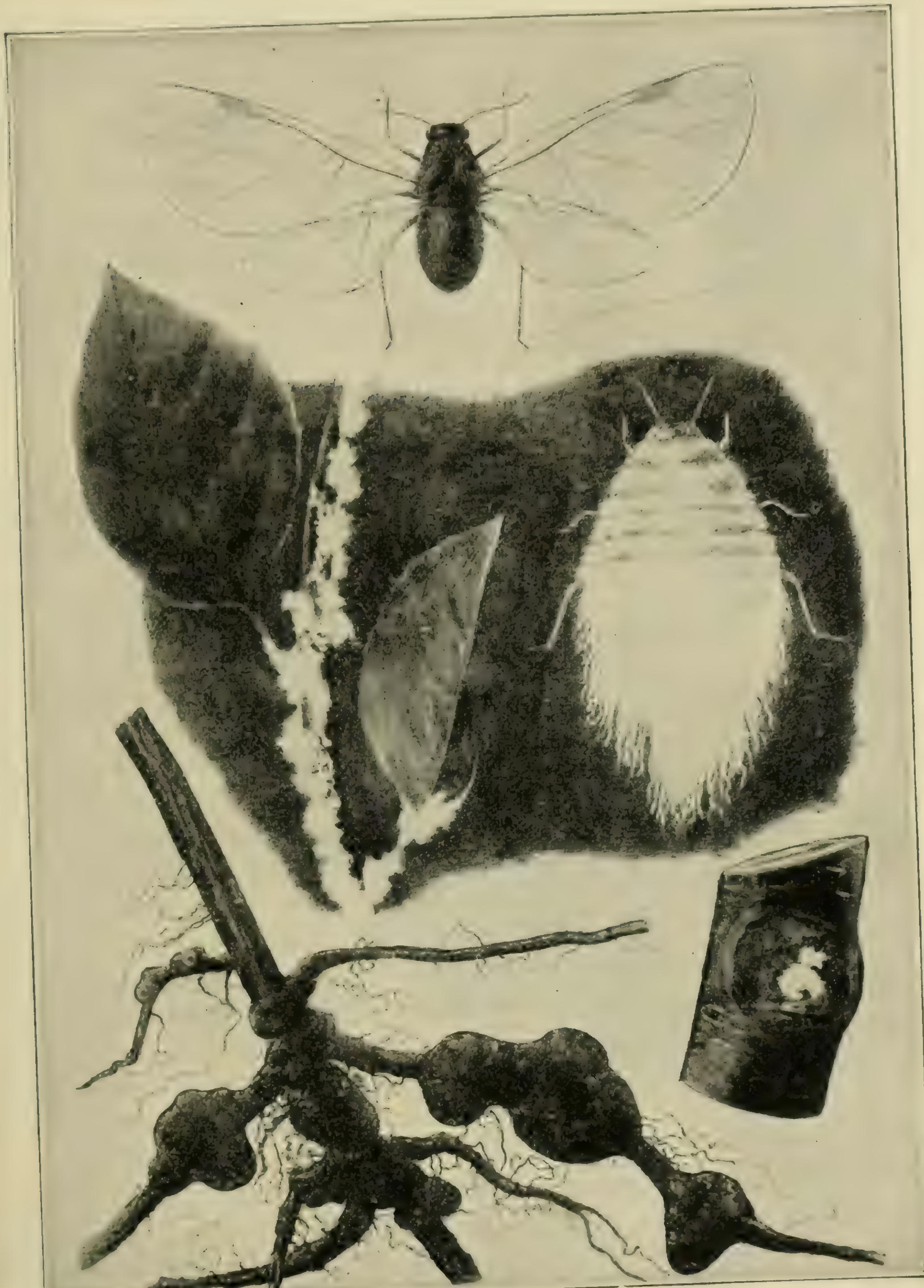


FIG. 356.—Woolly apple aphid, *Eriosoma lanigerum* (Hausman). Winged female above. At center, cluster of wax-covered aphids on twig, a single wingless female much enlarged at right. Roots showing characteristic galls produced by root-infesting form, below. A cluster of aphids in pruning scar at lower right. The last two reduced in size. *(From Ill. State Nat. Hist. Sur.)*

APPLE LEAFHOPPERS[1]

Importance and Type of Injury.—During late summer and fall, apple foliage becomes pale in color, with little specks of greenish white showing through from the under surface of the leaves. The new foliage becomes curled, the margins of leaves sometimes burned, and the fruits speckled with minute deposits of excrement. Many flimsy, white, shed skins of the leafhoppers are left on the under sides of the leaves. Severely injured leaves fall from the trees. One of the species[2] is also a pest of first importance on potatoes (see p. 475).

Plants Attacked.—Apple, rose, currant, gooseberry, raspberry, potato, sugar beet, bean, and celery, besides more than a dozen other plants, including weeds, grasses, grains, and shade trees.

Distribution.—General in the United States.

Life History, Appearance, and Habits.—The apple leafhopper[2] passes the winter as a full-grown insect, hidden away among the leaves under trees in the orchards and under any other shelter, such as bushes or woodlands in the vicinity of the orchard. The rose leafhopper[3] and another common apple leafhopper,[4] pass the winter in the egg stage under the bark of apple, rose, and other plants. Those hibernating as adults become active very early in the spring, the common species flying about and mating before the buds of the trees have begun to show green. When the leaves appear, the insects begin laying their eggs, which are pushed into the midrib, or larger veins and stems of the leaves. The first generation nymphs appear about the time the leaves become full-grown, or shortly thereafter. They, as well as the adults, feed by sucking the sap from the underside of the leaves. The nymphs are a pale green to greenish-white in color, wingless, but are very active, running forward, backward or sidewise, with equal ease. They reach maturity about midsummer, change to the adult stage, and deposit eggs for the second generation, which becomes full-grown during the early fall. Some of the species found in orchards differ somewhat in their life history from the above, but not to an extent to be of any significance in the application of control measures.

Control Measures.—Up to the present time, it has not been generally thought necessary to adopt any special means of controlling these insects. They have apparently been increasing in numbers during the last few years, and it may be necessary to control them in the near future. Should their injuries be deemed sufficient to warrant the expense of a nicotine or derris spray, this will be found quite effective in killing the young nymphs. The nicotine or derris should be used at a strength of 1 part to 800 parts of

[1] Several species of the Order Homoptera, Family Cicadellidæ.

[2] *Empoasca fabæ* Harris.

[3] *Empoa rosæ* (Linné.).

[4] *Empoasca maligna* Walsh.

water. One pound of potash fish-oil soap should be dissolved in each 25 gallons of the spray solution. Clean cultivation and proper pruning will aid in keeping down the numbers of these insects.

References.—U. S. Dept. Agr. Dept. Bull. 805, 1919; *N. Y. (Geneva) Agr. Exp. Sta. Bull.* 451, 1918; *Jour. Econ. Entomol.* Vol. 17, p. 594, 1924.

Clover Mite[1]

Importance and Type of Injury.—Occasionally during the dormant stage of the tree one will find small reddish or pinkish eggs attached to the surface of the bark around the buds and tips of the twigs. They are sometimes so numerous that the

Fig. 357.—Adult clover mite, *Bryobia prætiosa* Koch; greatly enlarged. (*From U. S. D. A. Farmers' Bull.* 1270.)

twigs have a reddish appearance. These are the eggs of a little creature related to spiders and ticks, and known as the clover mite. The eggs of some other species of mites are found in the same situations. The most characteristic and easily noticed indication of the presence of this mite is that of the eggs during the winter. In dry seasons the mites sometimes do considerable harm to apples. Infested foliage takes on a thin yellowish appearance and, during prolonged drouth, many of the leaves often fall from the trees.

Plants Attacked.—Apple, peach, prune, plum, pear, cherry, raspberry, and many forest trees and herbaceous plants.

Distribution.—Northern United States and Canada.

[1] *Bryobia prætiosa* Koch, Order Acarina, Family Tetranychidæ.

Life History, Appearance, and Habits.—The eggs are deposited by the adult females during the late fall. The mites hatch in the early spring and feed on the foliage of trees to some extent, though they depend mainly on the leaves of many herbaceous plants. They are eight-legged, reddish creatures, smaller than a pinhead, with the front legs much longer than the others (Fig. 357). Their injuries are more apt to cause damage to the stone fruits, particularly the plum. There are a number of generations throughout the growing season. Occasionally in the fall the mites will invade houses in large numbers, and, while they cause no damage inside the houses, their presence is extremely annoying.

Control Measures.—Spraying such as is ordinarily practiced for San José scale, using either lime-sulfur or the lubricating-oil emulsion, will clean up orchards infested by these mites. Occasionally it may be necessary to give a summer spray. In such a case, the summer-strength lime-sulfur, that is, 1 gallon of the liquid or 4 pounds of the dry lime-sulfur to 50 gallons of water, is effective in controlling these pests.

Reference.—Colo. Agr. Exp. Sta. Bull. 152, 1909.

European Red Mite[1]

Importance and Type of Injury.—This insect is becoming one of the most important fruit pests of the eastern United States and Canada. The injured trees, if the infestation is slight, show specking of the foliage; if the infestation is heavy, the foliage is pallid and sickly in appearance, and from a little distance has the appearance of being covered with dust. Many of the injured leaves drop. The fruit is undersized and of poor quality and color.

Trees Attacked.—This species has been taken from pear, apple, peach, plum, cherry many other trees and roses, and, on the Pacific coast, from citrus.

Distribution.—The European red mite is now known to be generally distributed throughout the United States east of the Mississippi River. In the West, it is known to occur in Arizona, California, Idaho, Oregon, Utah, and Washington.

Life History, Appearance, and Habits.—The mite passes the winter in the form of a somewhat flattened, spherical egg of a dull red color. The egg has a distinct style or stalk which, at least in the related citrus mite, is attached to the bark by several threads (Fig. 358). According to MacGregor and Newcomer, the guy threads are not made by the species that attacks deciduous fruits. The eggs hatch in the spring just before the time of apple bloom. The young mites crawl to the leaves and feed upon them, becoming full-grown in 2 to 3 weeks if the weather is warm, or after a longer period if cool. After mating, the females lay their eggs to the average number of about 30 or 35. Generation succeeds generation, all stages of the mites being found on the trees during the summer months. The average length of the life cycle is about 35 days, and there are from

[1] *Paratetranychus pilosus* C. and F., Order Acarina, Family Tetranychidæ. This mite was formerly called the citrus red spider, *Tetranychus mytilaspidis* Riley. According to McGregor and Newcomer it is distinct from the citrus red spider, and the latter should be called *Paratetranychus citri* McGregor.

four to six generations a year. The adult females are a little less than 1/50 inch in length, with four rows of long curved spines down the back. Hot, dry weather is favorable to the increase of these mites.

Control.—Thorough spraying during the dormant period with a good miscible oil or home-made soap-lubricating-oil emulsion has proved very effective in the control of this species. Where these sprays are applied, a satisfactory commercial control can be obtained. Spraying during the summer with commercial lime-sulphur at the rate of 1 gallon to 50 gallons of water, as recommended for the control of several plant diseases of the apple, will aid in controlling these mites. The same schedule should be

Fig. 358.—The citrus mite, a very close relative of the European red mite, *Paratetranychus pilosus* C. and F.; mites and one of their eggs showing the silken threads, like guy wires, that stretch from the leaf to the top of the egg stalk. (*From Quayle, Univ. of California.*)

followed as that recommended for the control of apple scab and blotch. The dormant spray, however, is the most satisfactory method of control.

References.—*Conn. Agr. Exp. Sta. Bull.* 252, 1923; *Dom. Canada Dept. of Agr., Entomol. Branch, Circ.* 39, 1925; *U. S. Dept. Agr., Tech. Bull.* 25, 1927; *Jour. Agr. Research* Vol. 36, No. 2, 1928.

Spring Cankerworm[1]

Importance and Type of Injury.—The foliage of the trees is eaten and skeletonized by measuring worms. The injury occurs just about the time the trees have come into full foliage. Silken threads are spun from branch to branch on the tree and from the branches to the ground. Brown and brownish-green measuring worms about 1 inch long spin down from the tree when it is jarred or shaken. Heavily infested orchards have much the appearance of having been scorched by fire.

Trees Attacked.—Apple, elm, and many other fruit and shade trees.

[1] *Paleacrita vernata* Peck, Order Lepidoptera, Family Geometridæ.

Distribution.—General, east of the Rocky Mountains; southeastern Canada; also in California.

Life History, Appearance, and Habits.—The winter is passed in the form of a naked brown pupa about ½ inch long by ⅛ inch thick. This pupa is found in the soil from 1 to 4 inches below the surface, and in greatest numbers close to the base of the trees. The moths begin emerging during warm periods in February and continue coming out until the end of April. The male moth is strongly winged and is of a dull-gray appearance, being much the color of a well-weathered piece of board. These moths may be seen flitting about from tree to tree at dusk in the spring evenings. The female moth is wingless, with a gray body (Fig. 360). On emerging from the ground, the female crawls to a tree and up

FIG. 359.—Larvæ of the spring cankerworm, *Paleacrita vernata* Peck; side view, showing the two pairs of prolegs near tip of abdomen. About twice natural size. (*From U. S. D. A. Farmers' Bull.* 1270.)

the trunk, or on to the branches, where she mates with the male and deposits her eggs in masses under the loose scales of bark. These eggs hatch in about a month into small greenish or brownish measuring worms, which at once begin to feed on the foliage. These worms (Fig. 359), which can be distinguished from the fall cankerworm by having only two pairs of prolegs, near the end of the body, feed for 3 weeks to 1 month, and, if abundant, may completely strip the foliage from the trees. At the end of the feeding period, they crawl or spin down to the ground where they excavate the small cells in which they change to the pupal stage and pass the remainder of the summer and the following winter.

Control Measures.—As the wingless female moths crawl up the tree to deposit their eggs, they may be stopped and trapped by placing a band of sticky material, such as tanglefoot, around the trunk of the tree at from 2 to 4 feet from the ground. When the moths are abundant, this band should be watched closely during March or April, as the trapped moths will often become so numerous as to bridge the band with their bodies, allowing those emerging later to cross without being caught. As the caterpillars are easily poisoned and do their feeding when the heaviest spray applications of the year are being made, they are never abundant in

well-sprayed orchards. They may be easily killed by a spray of arsenate of lead at the rate of 1 pound to 50 gallons of water. In unsprayed orchards, late spring and summer cultivation, with care to work close to the trunks of the trees, will help to some extent in reducing their injuries, by destroying the pupæ.

References.—Ohio Agr. Exp. Sta. Circ. 65, 1907; *U. S. Dept. Agr. Farmers' Bull.* 1270, 1922; *U. S. Dept. Agr. Dept. Bull.* 1238, 1924.

Fall Cankerworm[1]

This insect has practically the same life history as that of the spring cankerworm, and is controlled by the same measures. It differs from the other species in that the moths emerge in the fall, the insect passing the winter in the egg stage instead of in the pupal stage, as is the case with the spring species. The eggs are laid in single-layer groups, each egg having a flower-pot-like shape. The worms hatch and feed on the leaves in the same manner and at the same time as the spring cankerworm. In this species, the larva has three pairs of prolegs near the tip of the body (Fig. 360).

a

b

Fig. 360.—At left, female moths of fall cankerworm, *Alsophila pometaria* Harris; about twice natural size. The female of the spring cankerworm is similar but has a black stripe down the middle of the back and transverse rows of reddish spines on the upper side of the abdomen. At right, larva of the fall cankerworm, side view, showing the three pairs of prolegs near the tip of abdomen. About twice natural size. (*From U. S. D. A. Farmers' Bull.* 1270.)

Trees Attacked.—Apple, elm, and many other fruit and shade trees.

Distribution.—Much of the northern United States and southern Canada; also Colorado, New Mexico, and California.

Control Measures.—The control measures are the same as for the spring cankerworm, except that the trees should be banded in the late fall and not in the spring. Cultivation is of little value for this species, since it forms a tough cocoon.

[1] *Alsophila pometaria* Harris, Order Lepidoptera, Family Geometridæ.

Apple Flea Weevil[1]

Importance and Type of Injury.—This insect has been more destructive in Illinois than in any other State, but it is apparently spreading. Very small, dull black, snout beetles about 1/10 inch long puncture the newly opening leaves and buds of apple trees early in the spring. In the summer the leaves have numerous small holes eaten out

Fig. 361.—Injury to apple foliage by feeding of apple flea weevil adults, in midsummer. (*From Ill. State Nat. Hist. Sur.*)

from the underside, in cases of severe injury appearing as if riddled by very fine bird shot (Fig. 361). Yellowish-brown larval mines start from near the center of the leaf and run to small blister-like cells at the margin of the leaf.

Trees Attacked.—Apple, haw, winged elm, hazelnut, quince, wild crab, blackberry.

Distribution.—From Missouri and Illinois to eastern New York and southward to the Ohio River.

Life History, Appearance, and Habits.—The adults pass the winter in trash, grass, and leaves just at the surface of the ground, usually under apple trees. They become

[1] *Orchestes pallicornis* Say, Order Coleoptera, Family Curculionidæ.

active as soon as the buds begin to swell in the spring, some crawling up the trunk of the trees, while others mount the stems of weeds and grasses and fly to the newly opening buds. They feed for 1 or 2 weeks on the newly forming leaves, dropping to the ground during periods of cold weather and storms. When the leaves are about two-thirds grown, the females begin depositing their eggs along the midribs. These eggs hatch into small grubs, which feed between the upper and under surface of the leaf, eating out a little mine which is extended to the margin of the leaf. Here they hollow out a cell about 1/4 inch across, and in this complete their growth and change to pupæ, emerging as full-grown beetles during the latter part of May and June. The newly emerged beetles feed for from 2 weeks to 1 month on the leaves, and then seek shelter in the trash about the base of the trees and remain there until the following spring. There is but one generation each year.

Control Measures.—Thorough cultivation of the orchards which turns under the trash in which the beetles hibernate, is probably the most effective means of controlling this insect. Burning off the trash and leaves under the trees by means of a blow torch is also quite effective in destroying the overwintering beetles. Spraying with arsenate of lead and lime at the rate of 2 pounds of lead and 4 pounds of lime to 50 gallons of water, when the summer generation of beetles is feeding on the leaves, is also an effective control. Care should be taken to apply the spray to the undersides of the leaves. This spray is to be given only when the recommended spray schedule for the control of other apple insects (see p. 586) is not effective in controlling this insect. Spraying beneath the tree in late fall with a 15 per cent kerosene emulsion applied in sufficient amounts thoroughly to wet down the surface of the ground is another effective measure of control.

Reference.—Ill. State Nat. Hist. Survey Bull., Vol. 15, Art. 1, 1924.

Apple Leaf Skeletonizer[1]

Importance and Type of Injury.—This insect is not troublesome every year, but fluctuates greatly in numbers. It has been most injurious in the states of the upper

Fig. 362.—Apple leaf skeletonizer, larva, about five times natural size. (*From Ill. State Nat. Hist. Sur.*)

Mississippi Valley. The leaves at the ends of branches, and particularly in the top of the tree, are loosely folded and covered with a very light web or in some cases two or three leaves are webbed together. The leaves have the green fleshy part of the upper side eaten off entirely or in part, giving them a brownish, deadened appearance. In severe infestations, the foliage of the tree has the appearance of injury by severe drought or fire. Injury first becomes apparent in July, and usually is most severe during the first part of September.

Trees Attacked.—Apple, and sometimes plum and quince.

Distribution.—Most abundant in the central part of the United States.

Life History, Appearance, and Habits.—The insect passes the winter in the form of a brown pupa, about 1/3 inch long, usually in fallen leaves on the ground about the orchard. In late spring, it changes into a dark brown moth, about 1/3 inch long, with

[1] *Psorosina hammondi* (Riley), Order Lepidoptera, Family Pyralididæ.

wings mottled with silver bands (Fig. 363). These moths deposit their eggs on the leaves, and the first-generation caterpillars appear during June or July. These caterpillars (Fig. 362) are brownish green, about ½ inch long, with four shining black tubercles on the back just behind the head. They feed for about 3 weeks, and on becoming full-grown pupate in their webs on the leaves, emerging again as moths in August and depositing their eggs for the second generation of caterpillars, which appear during the latter part of that month and September. These caterpillars become full-grown by the approach of cold weather, and pupate in the leaves, which later fall to the ground.

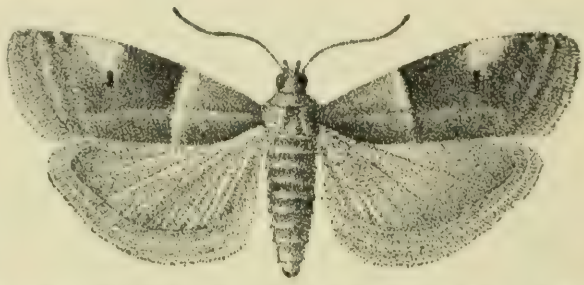


FIG. 363.—Apple leaf skeletonizer, *Psorosina hammondi* (Riley); adult with wings spread. About five times natural size. (*From Ill. State Nat. Hist. Sur.*)

Control Measures.—The ordinary spray schedule, where second- and third-generation codling moth sprays are regularly applied, will usually control this insect. Occasionally in orchards that have been neglected for a year or two, or in young orchards that have not come into bearing, it will be necessary to give a spray for this insect alone. Such a spray should be applied when the first appearance of injury occurs, in July, using arsenate of lead at the rate of 2 pounds to each 50 gallons of water, being careful to coat the upper surface of the leaves and drive the spray into the webs.

References.—*U. S. Dept Agr. Farmers' Bull.* 1270, 1922; *Fifteenth Rept. State Entomol. Ill.* pp. 58–64, 1889.

LEAF CRUMPLER[1]

Importance and Type of Injury.—The tough, curled cocoons, from ¾ to 1½ inches long, are surrounded by dead crumpled leaves and are tightly fastened to the twigs of the apple (Fig. 364). The buds are eaten off when they are just beginning to unfold. The fruit is sometimes scored and pitted by the feeding of the worms.

Trees Attacked.—Apple, plum, crab apple, quince, cherry, wild cherry, wild plum, and pear.

Distribution.—This insect, like the preceding one, is abundant in the upper Mississippi Valley and other northern states.

Life History, Appearance, and Habits.—The winter is always passed as a dark-brown, somewhat hairy caterpillar, about ⅓ to ½ inch long, enclosed in the tough curled grayish cases above mentioned. In the spring of the year, about the time that the apple buds open, these worms become active, loosen their cases from the points where they have been attached to the tree during the winter and, carrying the cases with them, begin feeding on the newly opening buds, later fastening several leaves together with silken threads. The latter part of May and during June, they change to the pupal stage, and later emerge as moths having a wing expanse of about ¾ inch. The wings are brownish in color, with white mottlings. The moths deposit their eggs on the new apple leaves, the young caterpillars of the next generation appearing in about 2 to 3 weeks. These begin feeding at once on the shoots and leaves, and con-

[1] *Mineola indigenella* Zeller, Order Lepidoptera, Family Pyralididæ.

struct the silken, curved, cornucopia-shaped cases in which they feed for the remainder of the summer. In the early fall they attach these cases securely to the twigs and there pass the winter. This insect is never destructively abundant in well-sprayed orchards.

Control Measures.—In orchards where this insect is causing injury, particular attention should be given to applying arsenate of lead in the cluster bud, calyx, and

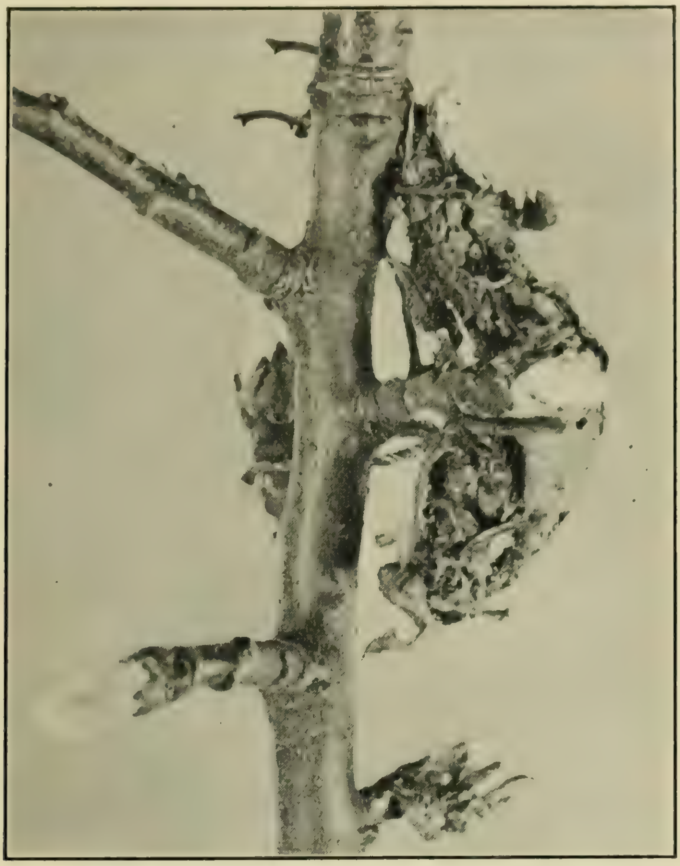


FIG. 364.—Winter nest of leaf crumpler enclosing larva; on apple twigs; slightly enlarged. (*From Ill. State Nat. Hist. Sur.*)

3-weeks' applications. No special sprays are required other than those regularly given for the control of codling moth, curculio, and other leaf-feeding insects.

References.—*U. S. Dept. Agr. Farmers' Bull.* 1270, 1922; *Fourth Rept. State Entomol. Ill.*, pp. 65–74, 1889.

Apple-leaf Miners

There are several species of these insects which mine in the leaves of apple. These miners are the young of various kinds of insects, some being beetles and some moths in their adult stages. They are not often of sufficient importance to warrant any special measures of control, with the exception of the apple flea weevil, which has been discussed.

Pistol-case Bearer[1]

Importance and Type of Injury.—Tiny, brownish-gray, tough, silken cases about ¼ inch long, curled or bent over at the top, so that they roughly resemble a pistol in outline are attached to the leaves, twigs, fruits, and branches, and stand at right angles

[1] *Coleophora malivorella* Riley, Order Lepidoptera, Family Coleophoridæ.

to them (Fig. 365, *b*). Small brown worms, enclosed in these cases, feed on the leaves and fruit and eat numerous small holes over the surface.

Trees Attacked.—Apple, quince, plum, cherry and haw.

Distribution.—General in apple growing sections, especially in the north.

Life History, Appearance, and Habits.—The winter is passed in the larval or worm stage inside the little pistol-shaped cases, the cases being firmly attached to the bark of twigs or branches. The partly grown larvæ within these cases are light brown with dark-brown heads. The insects begin feeding about the time the buds unfold in the

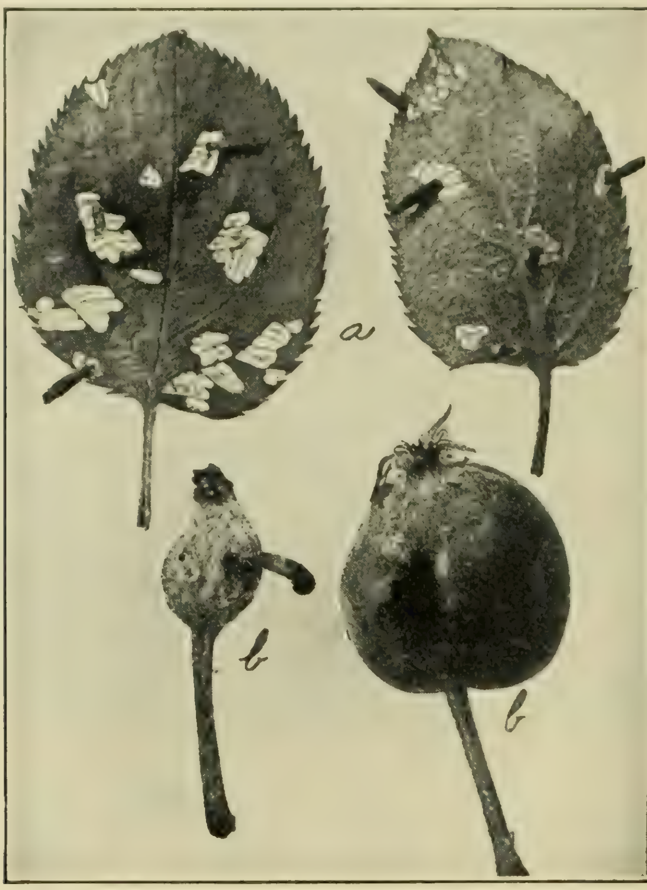


FIG. 365.—Case Bearers: *a*, cigar-case bearers and their work on apple leaves; *b*, pistol-case bearer and its work on young fruits. Natural size. (*From Lochhead, "Economic Entomology," P. Blakiston's Sons & Co., after Caesar.*)

spring, and reach the full-grown stage about June 1. They then change to the pupal stage, and a little later to small, mottled, gray moths which deposit their eggs on the underside of the leaves. The larvæ of the next generation appear during the late summer. These worms feed on the leaves until fall, when they migrate to the twigs and branches, where they pass the winter. This little insect is usually not abundant enough to cause commercial loss.

Control Measures.—The ordinary spray schedule applied to bearing trees will control these insects. Where this schedule is not followed, and the case bearers are abundant, a spray given in the cluster-bud stage, using arsenate of lead at 1 pound to 50 gallons of water, will kill most of them.

References.—*N. Y. (Cornell) Agr. Exp. Sta. Bull.* 124, 1897; *U. S. Dept. Agr. Farmers' Bull.* 1270, 1922.

Cigar-case Bearer[1]

This insect (Fig. 365, *a*) closely resembles the pistol-case bearer in its life history and habits. The case in which it lives is straight, and a new case is constructed in the spring when the overwintering larvæ start to feed. The young larvæ on hatching feed for a time in the leaves as miners. The control measures are the same as for the pistol-case bearer.

Reference.—N. Y. (Cornell) Agr. Exp. Sta. Bull. 93, 1895.

Bud Moths[2]

There are several species of bud moths which cause injury to the apple. They vary somewhat in their life history, but the means of control are the same for all species.

Fig. 366.—Spring foliage injury by bud moth on apple. Reduced one-half. (*From U. S. D. A. Farmers' Bull.* 1273.)

Importance and Type of Injury.—The larvæ of these insects eat out the newly opening buds (Fig. 366). The worms form small silken cases on the leaves or twigs, webbing together bits of the foliage. Small pits are eaten in the fruit, usually where a leaf lies in contact with it.

Trees Attacked.—Apple, pear, cherry, wild plum, haw, and possibly others.

Distribution.—Most important in the northern apple growing sections.

Life History, Appearance, and Habits.—The bud moths or bud worms pass the winter as small brown worms with black heads, about 1/4 inch long, in small silken cases attached to the axil of a twig or bud. These cases are inconspicuous and not easy to find. In the spring when the

[1] *Coleophora fletcherella* Fernald, Order Lepidoptera, Family Coleophoridæ.

[2] *Spilonota ocellana* Denis and Schiffermüller, and others, Order Lepidoptera, Family Olethreutidæ.

leaves begin to open, the little dark-brown caterpillars emerge from their hibernating cases and attack the buds and leaves. They eat out the buds, or cut off the stem of a leaf and, folding the edges together, attach it by silken threads to other leaves on the tip of the twig. They live in these cases for from 5 to 7 weeks, feeding at night. In early summer, the worms, which are then about ½ inch long, change within their silken homes into a brown pupal stage, and later emerge as grayish or brownish moths. The moths deposit eggs for the next generation, which appears from mid-June to mid-July. These little worms feed in much the same manner as those of the spring generation, although one of the species, the lesser bud moth,[1] mines the leaves to some extent.

Control Measures.—Where abundant, a strong arsenate of lead spray (2 pounds to 50 gallons of water) should be applied just as the buds are opening, and again in the cluster-bud and calyx sprays.

Reference.—*U. S. Dept. Agr. Dept. Bull.* 1273, 1924.

Fall Webworm[2]

Importance and Type of Injury.—The presence of this insect is indicated by loosely-woven, dirty white webs (Fig. 367) enclosing the

Fig. 367.—Nest or web of the fall webworm showing worms inside the web. Much reduced. (*From U. S. D. A. Farmers' Bull.* 1270.)

foliage on the ends of the branches. Several branches are sometimes covered by one of these webs. The webs enclose many pale-yellow, black-spotted, very hairy caterpillars which feed upon the surface of the leaves. These webs contain a quantity of black pellets of excrement from the worms, making them very unsightly.

Trees Attacked.—The fall webworm has been found feeding on more than 100 fruit, shade, and woodland trees. It does not attack evergreens.

Distribution.—General over the United States and southern Canada.

[1] *Recurvaria nanella* (Hübner), Order Lepidoptera, Family Olethreutidæ.

[2] *Hyphantria cunea* Drury, Order Lepidoptera, Family Arctiidæ.

Life History, Appearance, and Habits.—This insect passes the winter in the form of a brown pupa, enclosed in a lightly woven, silken cocoon. These cocoons will be found under trash on the ground or sometimes under the bark of trees. The moths begin emerging during the spring and continue to come out over a long period. They lay their eggs on the leaves, in masses, partly covered with white hairs, and the caterpillars hatching from these eggs construct webs over the leaves inside of which they feed. They continue feeding for about 1 month to 6 weeks, and upon becoming full-grown, crawl down the tree and construct the cocoons in which they pupate. The adults emerge late in the summer and lay eggs for a second generation of the worms in early fall, which, upon becoming full-grown, spin the cocoons in which they pass the winter as pupæ.

Control Measures.—Sprays for the second and third generations of codling moth will usually control the webworm. In young orchards, the webs may easily be removed by hand at less expense than will be incurred for spraying.

References.—*Ann. Rept. Smithsonian Inst. for* 1921, pp. 395–414, 1923; *Dom. Canada, Dept. Agr. Bull.* 3, n. s., 1922.

Eastern Tent Caterpillar[1]

Fig. 368.—Eastern tent caterpillar, egg masses on twig. About natural size. (*From U. S. D. A. Farmers' Bull.* 1270.)

Importance and Type of Injury.—This insect sometimes completely defoliates unsprayed orchards. Large thick webs, containing many hairy, brown caterpillars, are constructed in the forks and crotches of trees (Fig. 369). The leaves may be stripped from all the branches within a yard or more of these nests. These caterpillars do not feed within their webs, but congregate there during the night and in rainy weather.

Trees Attacked.—Wild cherry, apple, peach, plum, and more rarely witch hazel, beech, birch, barberry, oak, willow, and poplar.

Distribution.—This and closely related forms cover the United States.

Life History, Appearance, and Habits.—This insect passes the winter in the form of a dark-brown collar-like mass of eggs securely attached to, and often encircling, small twigs. These egg masses (Fig. 368) are about ¾ inch long by ½ inch in diameter. They have a shiny, varnished appearance. The eggs hatch early in the spring as soon as the apple leaves begin to unfold or a little earlier. The caterpillars (Fig. 370) gather in a near fork of the limbs, a colony often being made up of all the caterpillars hatching from several egg masses. Here they construct

[1] *Malacosoma americana* Fabricius, Order Lepidoptera, Family Lasiocampidæ.

their webs and sally forth to attack the newly opening leaves. They spin a fine thread of silk wherever they crawl, and in the course of a few days well-defined silken pathways lead from the nest to the favored feeding spots on the tree. As the caterpillars grow, their nest webs are enlarged. They become full-grown in about a month, scatter to some distance from the nest, and spin cocoons, usually on the tree trunk or some near-by object, in which they change to brown pupæ and later emerge as light-brown moths. The females deposit their eggs on the twigs for the next season's caterpillars, there being but one generation each year.

FIG. 369.—Eastern tent caterpillar. Larvæ and nest in crotch of wild cherry tree. Greatly reduced. (*From U. S. D. A. Farmers' Bull.* 1270.)

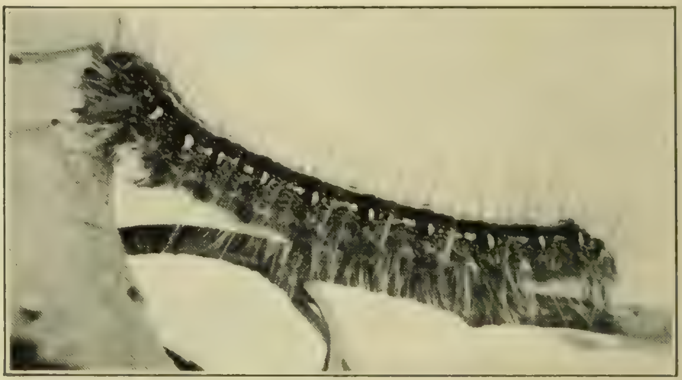


FIG. 370.—Larva of eastern tent caterpillar, *Malacosoma americana* Fabricius; slightly enlarged. (*From U. S. D. A. Farmers' Bull.* 1270.)

Control Measures.—Spraying with arsenate of lead, as ordinarily applied for the codling moth will control these insects. Where wild cherries or plums are very abundant in the vicinity of the orchard, it may be necessary to increase the strength of lead in the spray to 1½ pounds to each 50 gallons. Wild cherries and wild plums should not be permitted to grow within ¼ mile of the orchard. Cutting out these trees will also help in keeping down several other orchard insects.

Reference.—Conn. Agr. Exp. Sta. Bull. 177, 1913.

YELLOW-NECKED[1] AND RED-HUMPED CATERPILLARS[2]

Importance and Type of Injury.—Black- and yellow-striped caterpillars with yellow rings around their necks, or, in the case of the red-humped caterpillar, with a pronounced red hump just back of the head, with a row of spines projecting from it. These caterpillars will be found feeding in colonies on the leaves of the apple, pear, and some forest trees during July and August, completely defoliating small trees, or single branches on large trees.

[1] *Datana ministra* Drury, Order Lepidoptera, Family Notodontidæ.

[2] *Schizura concinna* Smith and Abbott, Order Lepidoptera, Family Notodontidæ.

Trees Attacked.—Apple, pear, cherry, quince, and many shade and forest trees.

Distribution.—General over the United States and Canada.

Life History, Appearance, and Habits.—The yellow-necked caterpillar passes the winter in the form of a brown naked pupa 2 or 3 inches below the surface of the ground. The red-humped caterpillar passes the winter as a full-grown larva in a cocoon on the ground, pupating early in the summer. Both emerge as medium-sized brown moths, which fly to the apple and related trees, where the females lay their eggs on the undersides of the leaves. These eggs are laid in masses of 50 to 100 (Fig. 371). The young caterpillars hatching from the eggs feed at first on a single leaf with their heads all pointing toward the outer edge of the leaf. At first they skeletonize the leaf, but within a few days they increase in size and of necessity spread over a number of leaves, sometimes all the leaves on a single twig or small branch, and begin consuming the entire leaf. During the course of their feeding, they sometimes migrate from one part of the tree to another. When disturbed, these caterpillars raise both ends of their bodies in the air, clinging to the plant with the prolegs near the middle (Fig. 372). They become full-grown in about 3 weeks, at which time the yellow-necked caterpillars enter the ground and change to the pupal stage, and the red-humped caterpillars spin their cocoons on the ground.

FIG. 371.—Egg mass of yellow-necked caterpillar, slightly enlarged. (*From U. S. D. A. Farmers' Bull.* 1270.)

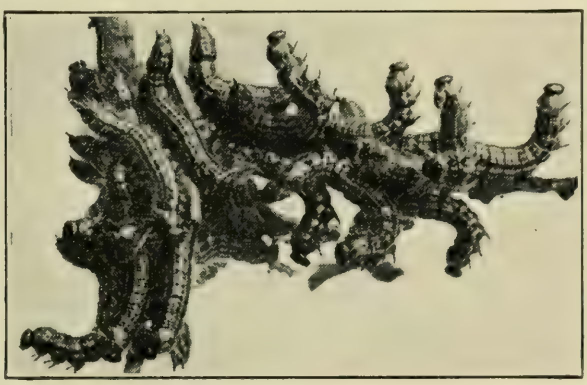


FIG. 372.—Cluster of larvæ of yellow-necked caterpillar, *Datana ministra* Drury; showing position assumed when alarmed. About natural size. (*From U. S. D. A. Farmers' Bull.* 1270.)

Control Measures.—In young orchards where the trees are 3 years old or under, a careful inspection of the trees during late July or early August will show where these insects are starting to feed, and they may be easily removed by hand and killed. A spray of arsenate of lead 1 pound to 50 gallons of water will effectively control them if they are abundant enough to warrant the expense of such an application.

Reference.—*N. H. Agr. Exp. Sta. Bull.* 139, 1908.

GRASSHOPPERS[1]

Grasshoppers are not generally considered as orchard pests, but occasionally during years of abundance when they have eaten most of the green growth in fields, or during periods of drought, they will migrate to orchards and sometimes completely strip the foliage from trees during July and August. Sometimes the bark is scarred and roughened by the feeding of these insects. Outbreaks of grasshoppers in the vicinity of orchards should be controlled before the insects migrate to the trees. This may

[1] Various species of Order Orthoptera, Family Locustidæ.

best be done by the use of the poison-bran bait (see p. 331). If the grasshoppers have already invaded the orchard the trees should be sprayed with arsenate of lead at the rate of 2 pounds to 50 gallons of spray, adding 4 pounds of hydrated lime to prevent burning the foliage.

Reference.—*Mont. Agr. Exp. Sta. Bull.* 148, 1922.

Codling Moth[1]

Importance and Type of Injury.—Apples attacked by this insect have holes eaten into the side, or from the blossom end, to the core. The seeds and core are tunneled and eaten by pinkish-white brown-headed worms about ¾ inch long when full-grown. Dark masses of frass or castings often protrude from the holes eaten in the apples. This is the most destructive insect pest of the fruit of the apple.

Plants Attacked.—Apple, pear, quince, wild haw, crab, English walnut, and several other fruits.

Distribution.—Throughout the apple-growing sections of the world.

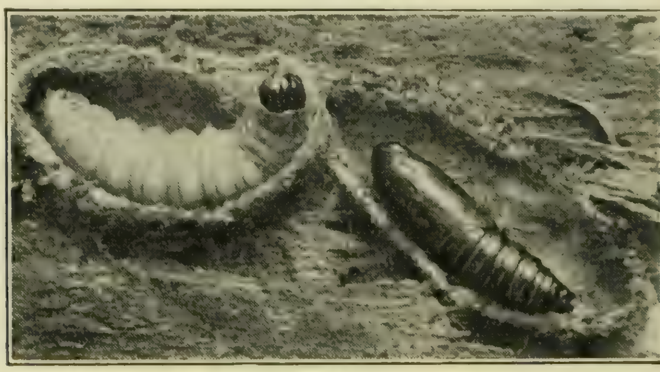


Fig. 373.—Codling moth larva and pupa within cocoons from beneath bark of apple tree, about twice natural size. (*From U. S. D. A. Farmers' Bull.* 1270.)

Life History, Appearance, and Habits.—The codling moth passes the winter in the full-grown larval stage in a thick silken cocoon (Fig. 373). The larvæ are pinkish-white caterpillars with brown heads and are about ¾ inch long. These cocoons are generally spun under loose scales of the bark on the trunks of apple trees, under other shelters about the base of the trees, or on the ground near-by. Many of the larvæ winter in or around packing sheds. They remain dormant, and are able to withstand low temperatures. A drop in temperature to $-25°$ F. or below, however, will kill many of the larvæ. During the winter, birds, especially woodpeckers, find and eat large numbers of the larvæ. In midspring the worms change inside their cocoons to a brownish pupal stage (Fig. 373) and, after a period of from 2 to 4 weeks or more, they emerge from the cocoons as grayish moths with somewhat irridescent, chocolate-brown patches on the back part or tip of the front wings. The moths (Fig. 375) have a wing expanse of from ½ to ¾ inch. During

[1] *Carpocapsa pomonella* Linné, Order Lepidoptera, Family Olethreutidæ.

the day the moths remain quiet, usually resting on the branches or trunk of the tree. The coloring of the wings is such that it blends with that of the bark, making the insect very inconspicuous. About dusk of the evening, if the temperature is above 60° F., they become active, mate, and the females lay their eggs. If the temperature is low, they remain quiet and few eggs will be deposited. Each female usually deposits more than 50 eggs during her lifetime. The eggs are white, flattened, pancake-shaped, and about $\frac{1}{25}$ inch in diameter (Fig. 374). The eggs of the

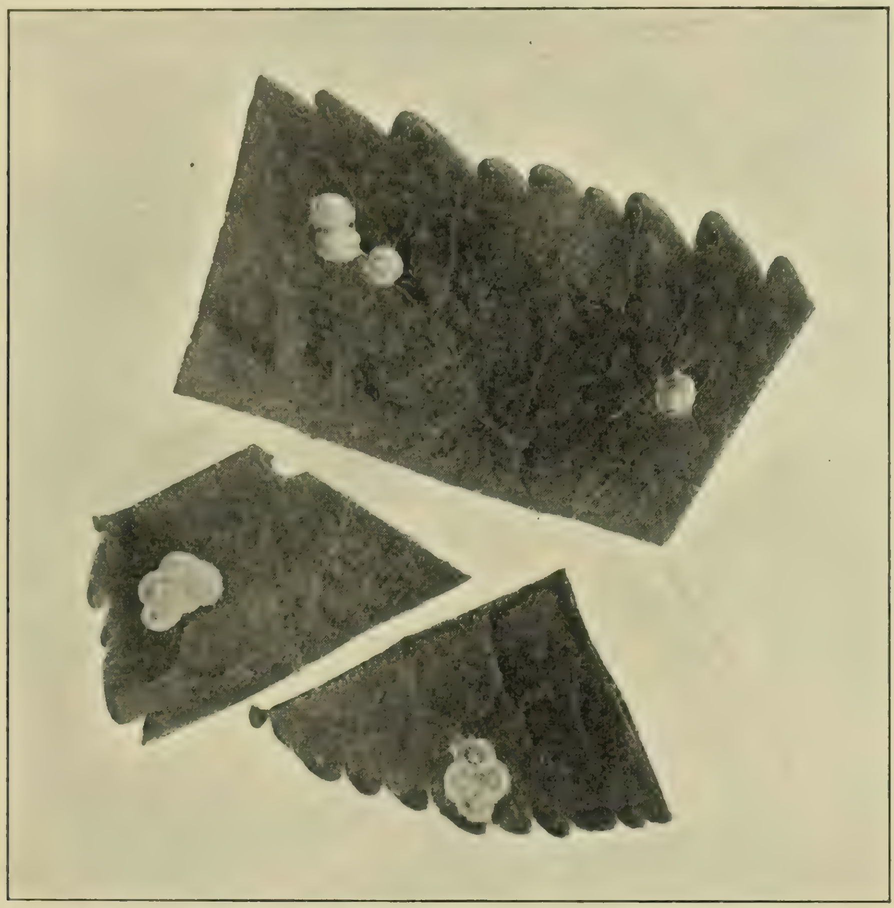


Fig. 374.—Eggs of codling moth on section of apple leaf; about five times natural size. (*From Ill. State Nat. Hist. Sur.*)

first generation are laid, one in a place, almost entirely on the upper side of the leaves, usually a short distance from a cluster of apples. Most of the eggs are laid 2 to 6 weeks after the apples have bloomed, and hatch in from 6 to 20 days, depending on the temperature and to some extent on the rainfall. The worms feed slightly on the leaves, but in a few hours crawl to the young apples and chew their way into the fruit, usually entering by way of the calyx cup at the blossom end. After entering the fruit they work their way into the core, often feeding on the seeds (Fig. 376). Some of the infested fruits drop from the tree and the larvæ complete their growth on the ground. Upon becoming

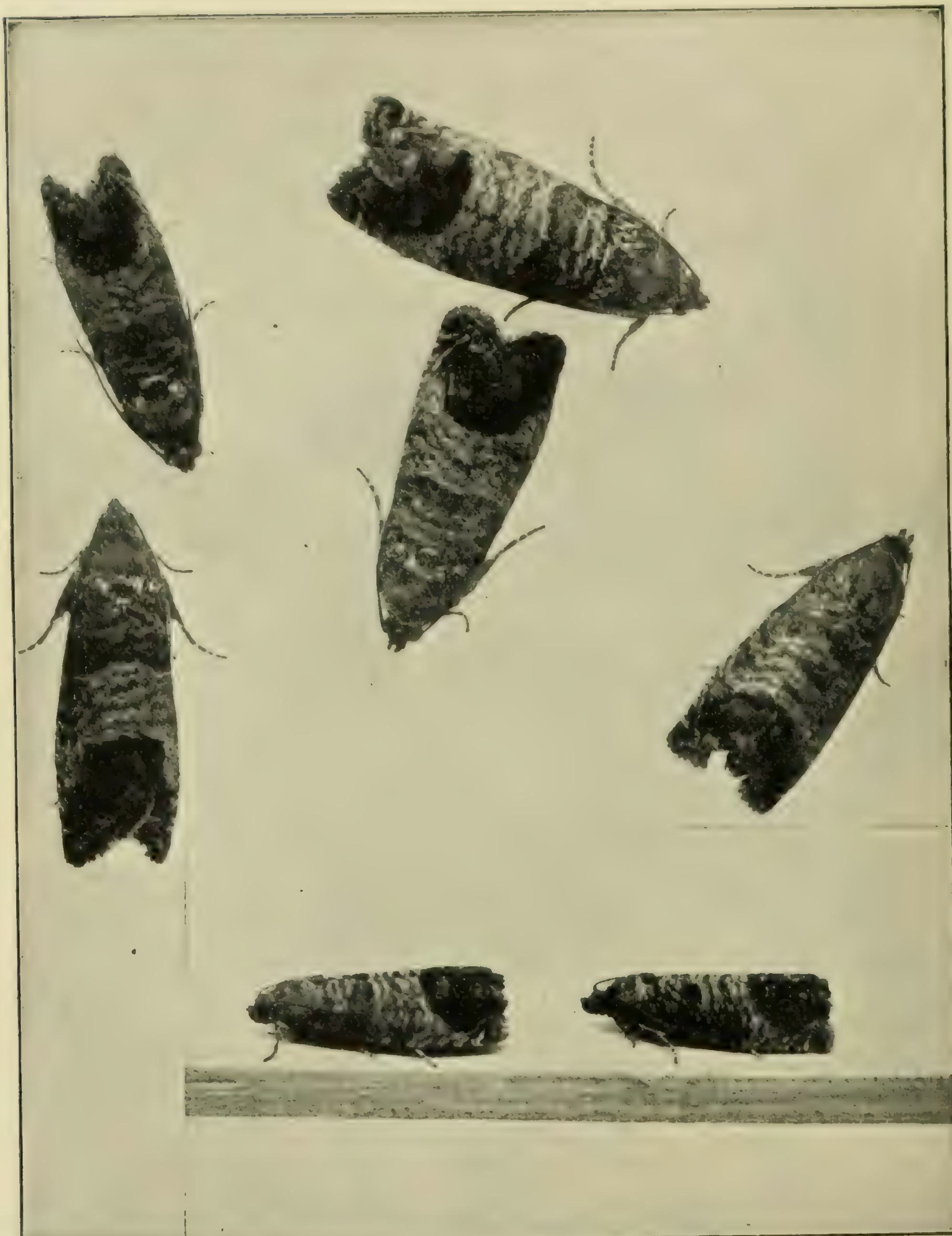


Fig. 375.—Adults of the codling moth, *Carpocapsa pomonella* Linné; about five times natural size. (*From Ill. State Nat. Hist. Sur.*)

full-grown, they burrow to the outside of the apple and either crawl to, or down, the trunk of the tree; or drop to the ground and crawl back to the trunk or to some other object. Under loose bits of bark or other shelter they spin their cocoons, and change as before to the pupa, and later to the adult, stage.

In the latitude of southern Illinois, there is nearly a full first, nearly a full second, and a partial third generation of this insect each season. In the latitude of northern Illinois, there is nearly a full first generation, a partial second, but no third generation. The emergence of the moths of the second generation extends over about 6 weeks, and eggs of this generation may be deposited in the northern part of the United States as late as mid-August, or even the first of September. In the South,

FIG. 376.—Apple injured by codling moth, showing larva in fruit. Slightly enlarged. (*From U. S. D. A. Farmers' Bull.* 1270.)

eggs may be laid as late as October. The hibernating larvæ consist of individuals from all generations.

Control Measures.—While the codling moth, if left to itself, may infest from 20 to 95 per cent of the apples in an orchard, it is generally possible to reduce the numbers of this insect so that less than 5 per cent of the apples will be injured.

Spraying with arsenate of lead at the rate of from 1 to 2 pounds of powder to 50 gallons of spray material is the standard remedy for the codling moth. It is highly important, however, that the sprays for this insect be applied at the proper time. The first and most important spray for codling-moth control is that known as the petal fall or calyx spray. This is applied when about three-fourths of the petals have fallen from the apple blossoms. The spray should not be applied when the trees are in full bloom, because of the danger of poisoning honeybees. Special care should be used to hit the open calyx end of the apples and fill the calyx cup with the spray. Careful spraying that fills the calyx

cup at this time will poison any young codling-moth caterpillars that try to enter the apples at the blossom end for the remainder of the season. If spraying is delayed for more than a week after the petals fall, the calyx cup will have closed, and it will be impossible to force the spray into it.

In the north-central states another application of spray should be made from 1 week to 10 days after the fall of the petals, and a third 3 weeks after the petals fall. These sprays are all for the first generation of codling moth. The second-generation larvæ usually begin to hatch about 9 weeks after the fall of the petals. However, this period is subject to considerable variation, sometimes as much as 3 weeks in different seasons. Owing to this fact, the time of the appearance of the second and third generations should be obtained in advance from the entomologist of the nearest state experiment station. If the notice of the time of appearance of the second-generation of codling moth cannot be obtained in this way, the spray for the second generation should be applied 9 weeks after the fall of the petals, and, in years when the codling moth is abundant, another spray should be given 2 weeks later. In the South, a spray for the third generation should be applied about August 15 and, during hot, dry years, another spray should be given to winter varieties of apples about September 1 (see Spray Schedule, p. 586). When fruit is sprayed shortly before picking, the spray residue should be removed before marketing.

It has been found that the development of the codling moth is largely dependent on the temperature. Development is nearly at a standstill at temperatures below 50° F., and is retarded above 86° F. Temperatures above 50° F. and below 86° F. have been called *effective temperatures*. It has been found that approximately 550 day-degrees of effective temperature are required to bring about the hatching of the earliest larvæ of the first generation, and 1,000 day-degrees additional for hatching of the first larvæ of the second generation and so on for each additional generation. A spray should always be applied just before the time of the hatching of the first larvæ of any generation. For a fuller discussion of this method of forecasting the time of appearance of any generation of the codling moth, see the first reference on page 573.

Aside from spraying, there are several other measures which help in keeping down the codling moth. These consist of a thorough clean-up of the orchard, scraping the loose bark from old trees and removing rubbish from the ground. In cases of exceptional abundance, the trees should be banded during the summer. To get the best results from banding, place a strip of tar paper, 4 or 5 inches wide, tightly around the tree at a height of about 2 feet from the ground. Allow the ends to overlap slightly, fastening them with a large tack. These bands should be examined at least once every 10 days and the codling-moth larvæ under them killed.

The bands should be in place not later than 5 weeks after petal fall; June 1 in the latitude of southern Illinois, and June 15 in the latitude of northern Illinois. Experimental work has shown that the tar building-paper bands are more attractive to the codling moth larvæ than bands of burlap or cloth. Recent experiments have shown that it is possible to treat bands with certain chemicals so that they will kill most of the larvæ that seek shelter under them. Removing cull apples from the orchard, and a thorough clean-up of refuse and rubbish around the packing shed also will help in keeping down the numbers of this insect. The codling moth is preyed upon by many insect enemies, but these are never sufficient to reduce its numbers so that artificial control measures may be omitted.

References.—Ill. Nat. Hist. Survey, Bull., Vol. 14, Art. VII, 1922; *New Mex. Agr. Exp. Sta. Tech. Bull.* 127, 1921; *U. S. Dept. Agr. Dept. Bull.* 932, 1921; publications of nearly all experiment stations.

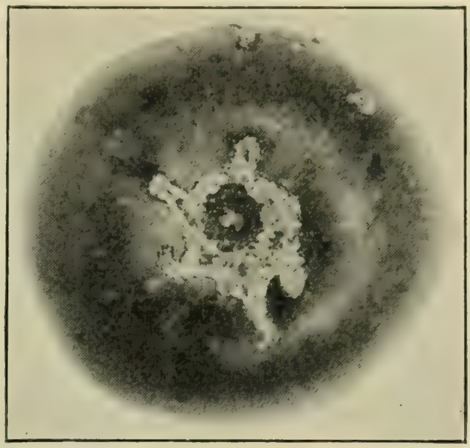


FIG. 377.—Work of lesser apple worm in calyx end of apple. (*From U. S. D. A. Farmers' Bull.* 1270.)

Lesser Apple Worm[1]

Importance and Type of Injury.—The lesser apple worm is much like the codling moth in its habits and manner of feeding on the apple. The larva often works for a time just under the skin of the apple, making a broader and more shallow mine than does the codling moth (Fig. 377). In common with the codling moth, many of these larvæ enter the apple at the calyx end, sometimes burrowing out a cavity clear around the calyx. These mines are smaller than those of the codling moth, and frequently do not extend clear into the core. The injury, while sufficient to prevent an apple from grading as first-quality fruit, is not usually as severe as that caused by the codling moth.

Trees Attacked.—Apple, pear, peach, plum, quince, haw, crab, black knot of plum, and galls on elm and oak.

Distribution.—Central United States, New England, and southeastern Canada, and British Columbia.

Life History, Appearance, and Habits.—This insect passes through the winter in the larval stage in a cocoon on the trunk of the tree, or in any other shelter where it may find protection. The cocoon is about half the size of that of the codling moth, and is not as thick and strong. The adult moths are abroad in the orchard from 2 to 4 weeks after the petals fall. The moth, which is about ¼ inch long, has brown wings shading from dark to light from tip to base. The eggs are smaller than those of the codling moth, but very similar in appearance. They are laid on the leaves or fruit and the worms hatching from them feed in the apple for about 3 weeks. The larva closely resembles the codling worm but is not over one-half its size, being about ⅓ inch long. Upon becoming full-grown, they sometimes spin their cocoons within the apple and there change to the pupa and later to the moth stage. In most cases, however, they leave the apple, spinning the cocoon on the trunk or larger branches

[1] *Laspeyresia prunivora* Walsh, Order Lepidoptera, Family Olethreutidæ.

of the tree or other protected places. There are two or three generations of this insect a year, the larger number occurring in the South.

Control Measures.—The lesser apple worm is so much like the codling moth in its habits, that the control measures are practically the same. It is considered somewhat harder to poison, especially the second and third generations, which do very little feeding outside the apple; but, in general, where careful, thorough spraying is done for the codling moth the lesser apple worm will be controlled.

References.—*U. S. Dept. Agr. Farmers' Bull.* 1270, 1922; *N. Y. (Cornell) Agr. Exp. Sta. Bull.* 410, 1922.

Green Fruit Worms[1]

Importance and Type of Injury.—It frequently happens that an orchardist will find large holes eaten in the young apples, from three to four weeks after the petals fall. This injury is often caused by the larvæ of several species of moths which are known as green fruit worms.

Fig. 378.—Green fruit worm hollowing out a small apple. About natural size. *From Ill. State Nat. Hist. Sur.*)

When the apples are about the size of marbles, one may find the entire side or end of the fruit eaten out (Fig. 378). A close examination will often show that the majority of the young apples on a single branch or twig have been injured in this way. Usually one will be able to find a greenish or greenish-white worm from ¼ to 1¼ inches long somewhere upon the twig or branch, possibly feeding actively on the side of the apple. The injury is sometimes severe enough entirely to destroy the apple, but more often the fruit will continue to grow but will be worthless. These worms are seldom very abundant in an orchard.

Plants Attacked.—Nearly all the deciduous forest trees, all common tree fruits and some field crops.

Distribution.—General over the eastern United States and Canada.

Life History, Appearance, and Habits.—The winter is passed in two stages, but most commonly as a grayish moth with a wing expanse of a little over 1 inch. These moths hibernate in woodlands or sheltered places about orchards. A small percentage of the insects pass the winter in the pupal stage. This stage will be found in a closely woven, silken cocoon 2 or 3 inches beneath the surface of the soil. Those that have gone through the winter as pupæ emerge as moths early in the spring. The moths fly to the orchards as soon as growth starts, and deposit their eggs, one in a place, on the twigs and branches of trees, the moths dying after they have completed egg laying. There are at least three species, and probably more, which cause this injury. All of these larvæ are of a pale grass-green color, some marked with whitish stripes down each side of the body and a narrower stripe down the middle of the back. When full-grown, they are fat, squatty-appearing worms from 1 to 1¼ inches in length. The full-grown stage is usually reached during the first of June; then the caterpillar descends from the

[1]*Graptolitha bethunei* Grote and Robinson, *Graptolitha laticinerea* (Grote), *Graptolitha antennata* Walker, and others, Order Lepidoptera, Family Noctuidæ.

tree, burrows into the ground, and there constructs the cocoon in which it changes to the pupal stage. Aside from feeding on apples, the insects have occasionally become abundant enough to cause defoliation of woodland trees, and have been known to destroy a twenty acre field of corn in Illinois.

Control Measures.—Green fruit worms are often plentiful and quite destructive in orchards receiving the regular codling moth sprays. This is due mainly to the fact that these worms are so large by the time the calyx spray is applied that they can withstand a dose of poison sufficient to kill smaller insects such as the codling moth, lesser apple worm, and curculio. The most effective measure for controlling green fruit worms is by heavy applications of poison early in the season, when the worms are still small. In orchards where these insects are abundant, the trees should be thoroughly sprayed with 2 pounds of arsenate of lead to each 50 gallons of the spray mixture, at the cluster-bud stage of the apple; that is, the spray applied when the fruit buds are just beginning to separate, but before the petals have opened. This is practically the only effective method of controlling these insects.

References.—*U. S. Dept. Agr. Farmers' Bull.* 1270, 1922; *N. Y. (Geneva) Agr. Exp. Sta. Bull.* 423, 1916; *Dom. Can. Dept. Agr. Entomol. Branch, Tech. Bull.* 17, 1919.

Fruit-tree Leaf Roller[1]

Importance and Type of Injury.—From shortly after the buds open to about 3 weeks after the petals fall, small, greenish to greenish-brown

Fig. 379.—Mature apple showing injury caused by fruit-tree leaf roller feeding on the young fruit. (*From Ill. State Nat. Hist. Sur.*)

worms will be found feeding on the leaves, buds, and small fruits of the apple. In most cases, a light web is spun about several leaves, and these are rolled or drawn together, often enclosing a cluster of newly formed apples.

Small apples have cavities eaten out of the side or center, somewhat like those made by the green fruit worm. The trees may be partially to completely defoliated, with numerous fine, white, silken webs over the

[1] *Archips argyrospila* Walker, Order Lepidoptera, Family Tortricidæ.

bark and trunk. At picking time the apples have deep, russeted, elongate scars in the side (Fig. 379).

Trees Attacked.—Nearly all kinds of fruits, many forest trees, and some of the bush fruits.

Distribution.—General in the apple-growing sections of the United States and Canada.

Life History, Appearance, and Habits.—The fruit-tree leaf roller passes the winter in the egg stage. These eggs are laid in masses of 30 to 100,

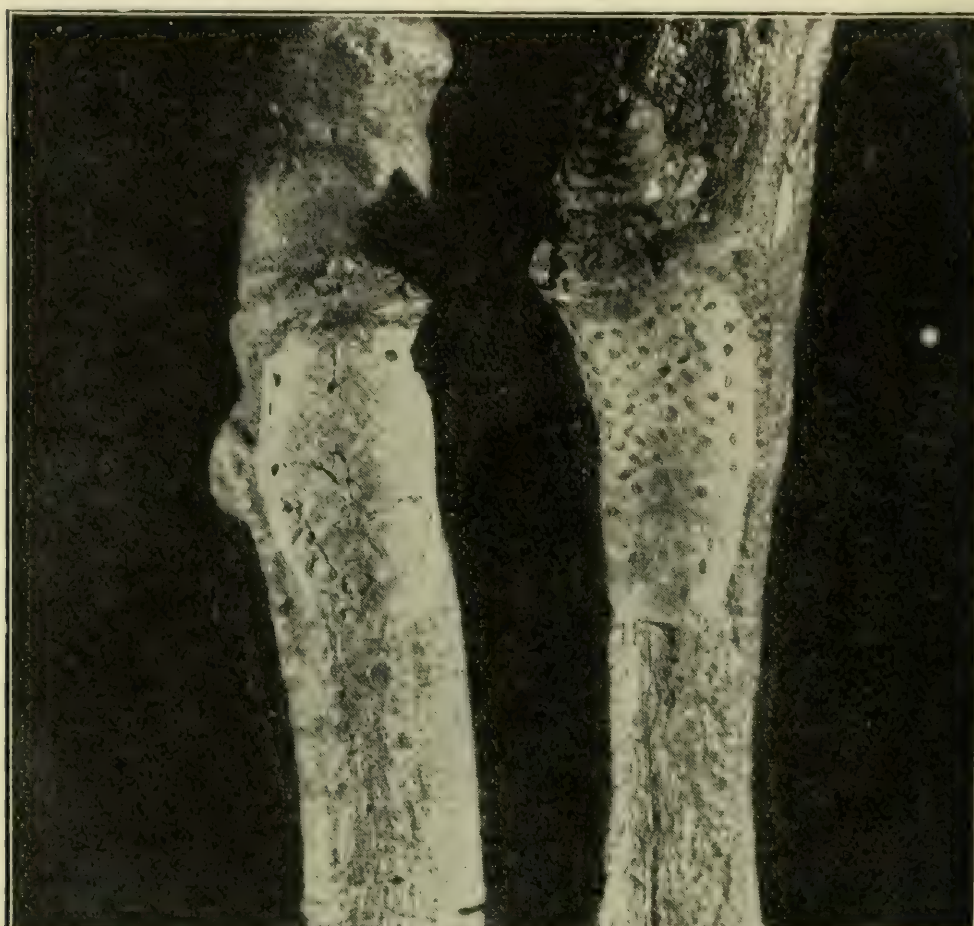


FIG. 380.—Egg masses of the fruit-tree leaf roller on twigs of apple about five times natural size. Egg mass on the right shows exit holes of newly hatched larvæ. (*From Ill. State Nat. Hist. Sur.*)

and are closely plastered on the twigs, branches, and occasionally on the trunk of the tree. They are covered with a smooth coating of dull-brown or gray, varnish-like material, which protects them from the weather and prevents the individual eggs from showing in the cluster (Fig. 380). The egg masses blend almost perfectly with the bark on which they are deposited, making it extremely difficult to see them. The eggs begin hatching about the time the apple fruit buds are beginning to separate in the spring. The young worms crawl to the leaves, and begin feeding as above stated.

They vary somewhat in color, but in general are pale green without special body markings except for a brown head and brown plate just back of the head. Upon becoming full-grown, the worms are about ¾ inch in length. They pupate within the folded or rolled leaves, or crawl to the trunk or branches of the tree and there construct a somewhat flimsy cocoon. From this cocoon the moths, which are about ½ inch long with brownish front wings mottled with pale gold (Fig. 381), emerge during late June or July. Within a few days they mate and lay their eggs in the situations above described. The insect remains in the egg stage until the following spring. There is but one generation each year.

Fig. 381.—Adult female of the fruit-tree leaf roller, about twice natural size. (*From Ill. State Nat. Hist. Sur.*)

Control Measures.—While it would appear that the fruit-tree leaf roller might be controlled by poison sprays, actual experience in the orchard has shown that it is very difficult to prevent damage by this insect, even with heavy applications of poison. Very effective control has been obtained by thoroughly spraying the trees, during the dormant stage, with a boiled or cold-mixed lubricating-oil emulsion, at a strength of 6 per cent oil. Commercial miscible oils and oil emulsions of several kinds have been found effective for this work. They should be used at the strength recommended by the manufacturers. In spraying for the control of the fruit-tree leaf roller, very thorough work must be done, as it is necessary, in order to prevent hatching, to hit each egg mass and the egg masses are often laid on the smaller twigs and in the axils of the twigs.

References.—*Colo. State Entomol. Circ.* 5, 1912; *Mont. Agr. Exp. Sta. Bull.* 154, 1923; *Idaho Agr. Exp. Sta. Bull.* 137, 1925; *Ill. State Nat. Hist. Survey, Entomol. Series Circ.* 9, 1926.

Plum Curculio[1]

Importance and Type of Injury.—This snout beetle, which is primarily a pest of peach, plum, cherry, and other stone fruits, is sufficiently fond of the apple to make it second to the codling moth in importance as a pest of

[1] *Conotrachelus nenuphar* Herbst, Order Coleoptera, Family Curculionidæ.

this fruit. Injury on apple is shown by small, crescent-shaped cuts in the skin of small fruits, some of them with a little round hole opposite the concave side of the crescent, into which an egg is usually deposited (Fig. 383). Later these injuries develop into swellings or knots, protruding from the surface of the fruits and each with a small puncture in the skin at its apex. Apples will sometimes show depressions instead of swellings, with the curculio injury at the center of the depression. An examination

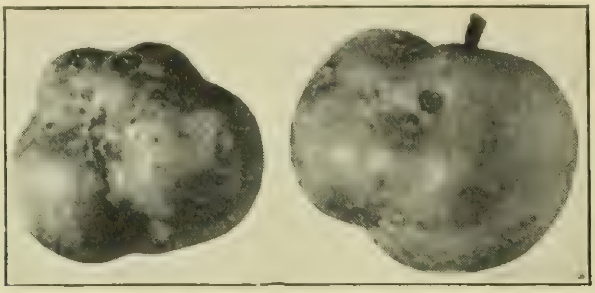


FIG. 382.—Apples deformed by the plum curculio. *(From U. S. D. A. Farmers' Bull. 1270.)*

of such apples will sometimes reveal a grayish-white, curved worm inside. Many of the infested fruits drop during late May and June. During late summer, numerous, round, feeding holes or punctures are made through the skin of the apple and other fruits, and the flesh is eaten out beneath these punctures (Fig. 384). The infested apples are often hard, knotty, and misshapen (Fig. 382).

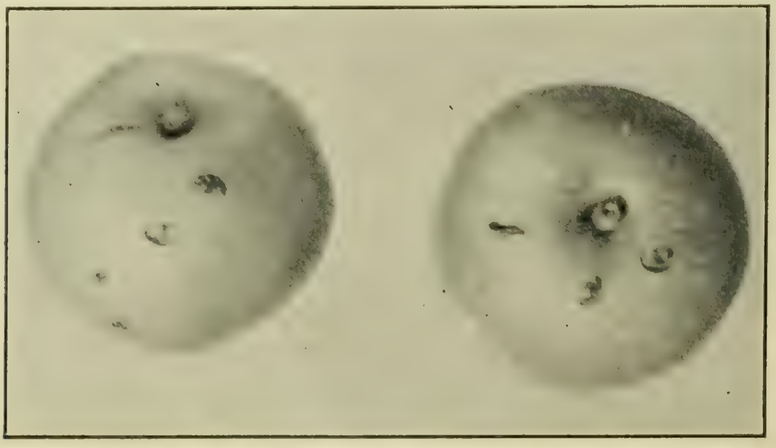


FIG. 383.—Egg punctures made by the plum curculio on apples. *(From Ill. State Nat. Hist. Sur.)*

Trees Attacked.—Plum, pear, apple, peach, cherry, apricot, prune, nectarine, quince, and other pome and stone fruits.

Distribution.—East of the Rocky Mountains in the United States and Canada.

Life History, Appearance, and Habits.—This insect passes the winter as a dark-brown snout beetle about ⅓ inch long, with grayish or whitish patches on its back and four humps on the wing covers (see Fig. 385). A

strong curved snout, about one-third the length of the body, projects forward and downward from the head of the insect. These beetles seek protection in and around orchards or near-by woodlands, where they find

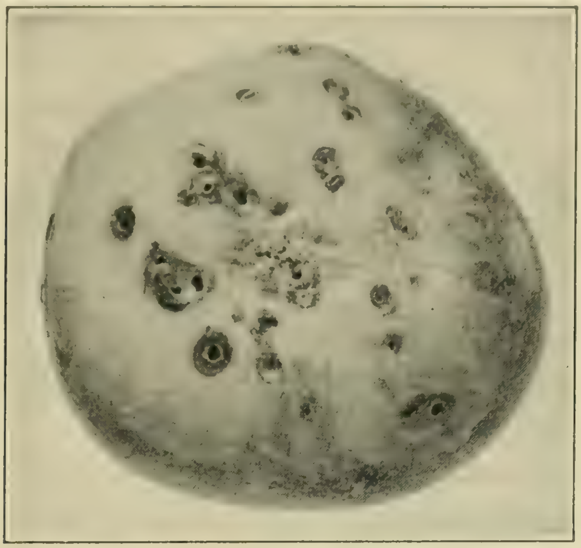


Fig. 384.—Late summer feeding punctures of the plum and apple curculios, on apple (*From Ill. State Nat. Hist. Sur.*)

shelter during the winter. They become active about the time the apples bloom, or possibly in some years a little earlier than this. They fly to the trees, feed on the newly forming apples, mate, and the females begin

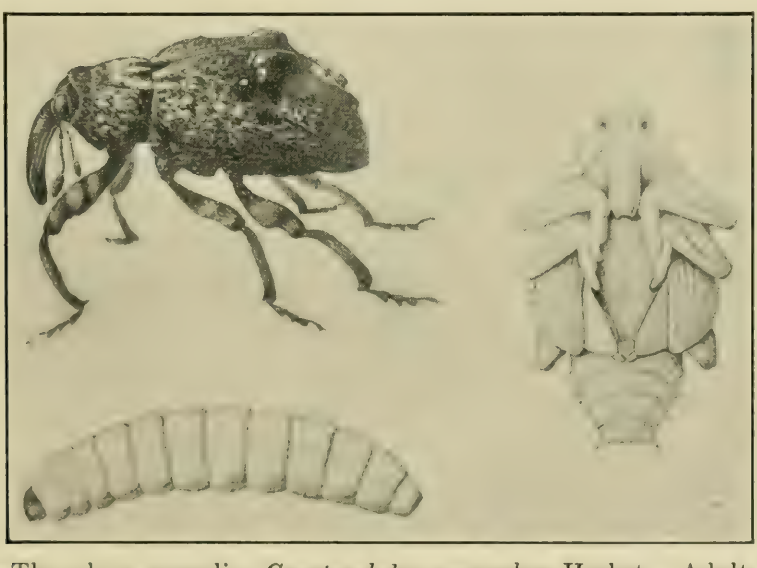


Fig. 385.—The plum curculio, *Conotrachelus nenuphar* Herbst. Adult above at left in side view; larva below at left, side view; pupa at right, ventral view; about four times natural size. (*From Ill. State Nat. Hist. Sur.*)

laying their eggs. In this operation, the female cuts a crescent-shaped slit in the skin of the fruit and a small puncture just at the apex on the inside of the crescent, and then deposits her egg in this puncture, forcing it under the skin and into the fruit (Fig. 383). Upon hatching the young

grub eats into the flesh of the apple to the core and seeds. The curculio larva is grayish-white, legless, curved-bodied, with a small brown head (Fig. 385). It is about 1/3 inch long when full-grown. Infested apples nearly always fall to the ground before the curculio has completed its growth. When the apple remains on the tree, the larva does not develop. Upon becoming full-grown the insect leaves the apple and works its way into the ground, excavating a little cavity, in which, after about 2 weeks, it changes to the pupal stage (Fig. 385). About 1 month after the larva enters the soil, it changes to the adult insect, and the summer generation of beetles begins to appear in the orchard. In the latitude of central Illinois, most of the beetles come out during July. In the southern states, there is, in some seasons, a partial second and possibly sometimes a partial third generation. North of the 38° north latitude there is probably only one generation annually. The adult beetles on emerging fly to the fruit and, during the remainder of the summer, feed on the apples, making small holes through the skin, and with the aid of their curved snouts eating out a cavity in the flesh beneath these holes. Some of them begin seeking winter quarters in August, while others remain on the trees as late as mid-October or the first of November, in the South.

Control Measures.—To reduce injury by curculio in badly infested orchards, it is often necessary to combat this insect by spraying, cultivation, and the removal of the dropped fruit. Orchards that have not been cultivated for a number of years are usually more seriously infested with the curculio than orchards where the ground is kept clean, as they afford better wintering places for the insects. Orchards close to woodlands are nearly sure to suffer injury by this insect, especially the rows of trees nearest the woods. For this reason it is important to keep an orchard in a clean condition with as little brush or woodland as possible in the vicinity. Keeping the orchard clean-cultivated during June and July also is of great help in controlling the curculio. If the surface of the ground is disked or harrowed so that the soil is stirred for a depth of 3 or 4 inches, the cells of earth in which the curculio pupates will be broken up and, even though the insect is not crushed by the cultivating tools, it will be killed. Such cultivation of heavily infested orchards has been found of great help in reducing the numbers of the curculio.

Careful spraying or dusting, properly timed, is of great importance as a means of controlling the curculio. Where the insect is abundant, the spray schedule as given for the codling moth should be applied, with one additional spray put on 1 week after the calyx or petal-fall spray and followed with another spray a week later. Arsenate of lead is the poison most commonly used, at 2 pounds to 50 gallons of spray material, or 15 pounds in 100 pounds of dust.

In badly infested orchards it will be of advantage to pick up and destroy the dropped apples during June and July if this can be done at

small expense. Once well established in an orchard, the curculio may become such a serious pest that it will warrant taking the most vigorous measures possible to secure effective control.

References.—*U. S. Dept. Agr. Bur. Entomol. Bull.* 103, 1912; *U. S. Dept. Agr. Dept. Bull.* 1205, 1924; *Mo. State Fruit Exp. Sta. Bull.* 21, 1909.

Apple Curculio[1]

Importance and Type of Injury.—This insect is somewhat like the plum curculio in general appearance, but differs from it in its habits and manner of injury to the apple. It is not as important as an apple pest. The apples attacked are misshapen, knotty, and undersized. Small holes are eaten in the sides or ends of the apple, many holes often being made close together causing a deadened area on the skin of the apple (Fig. 384). There are sharp pointed protuberances on the apple marked at their center by a small puncture in the skin. Infested apples sometimes drop as is the case with the plum curculio. The injury may be distinguished from that of the plum curculio by the larger number of punctures close together through the skin and the larger deadened areas on the fruit surface as above mentioned.

Trees Attacked.—Apple, haw, wild crab, quince, and some others.

Distribution.—East of the Rocky Mountains.

Life History, Appearance, and Habits.—This insect, like the plum curculio, passes the winter in the full-grown or beetle stage. It is of a brown to light-brown color, with four very distinct humps on the back (Fig. 386). The snout is longer and more slender than that of the plum curculio, being nearly as long as the insect's body. The head is small, and the body enlarges toward the base of the abdomen, giving the insect a distinct triangular outline when viewed from above. This insect hibernates, so far as we know, in much the same situations as the plum curculio. It attacks the apple somewhat later in the spring, usually not being found in orchards until the apples are at least $\frac{1}{2}$ inch in diameter. The females excavate cavities in the fruit, in which they lay their eggs, but do not make the crescent-shaped slits characteristic of the egg-laying scars of the plum curculio. The eggs are deposited from May to mid-July each insect laying from 25 to 70. The feeding of the larva of the apple curculio very seldom causes the fruit to drop, as does the plum curculio. This insect also differs in its habits from its near relative in that the larvæ pupate within the apple, the adults appearing in July and August. These beetles do very little feeding, and go into hibernation by the first of September. So far as we know, there is only one generation of this insect annually.

[1] *Tachypterellus* (*Anthonomus*) *quadrigibbus* (Say), Order Coleoptera, Family Curculionidæ.

Control Measures. General measures of orchard sanitation are fully as important in the control of this insect as for the plum curculio. It is also highly important that haws and wild crabs should be cut down, if growing within ½ mile of the orchard. These trees are the native food plants of the apple curculio, and the insects will usually be found on them in greater numbers than on the apple. Owing to the fact that the larvæ pupate within the fruit largely on the tree, summer cultivation is of no advantage in the control of this insect. It is also difficult to kill by means of poison sprays, as the adult beetles feed but little on the surface of the

FIG. 386.—Apple curculio, *Tachypterellus quadrigibbus* (Say); showing the long snout of the beetle and position assumed when disturbed. About two and one-half times natural size. (*From Ill. Agr. Exp. Sta. Bull.* 98.)

fruit, taking most of their food through their long beaks from the flesh of the apple beneath the skin. On the whole, it may be said that keeping the orchard and vicinity free from grass, bushes, or other places offering hibernating quarters for the adult insects, is the most effective means of controlling the apple curculio.

References.—Ill. Agr. Exp. Sta. Bull. 98, 1905; *W. Va. Agr. Exp. Sta. Bull.* 126, 1910.

Apple Red Bugs

Importance and Type of Injury.—The apple-growing states in the East often suffer considerable losses from certain sucking insects known as

apple red bugs. Infested fruit (Fig. 387) has a pitted or dimpled appearance, is dwarfed in size, and somewhat hard or woody in texture and sometimes russeted in spots. The general appearance is somewhat like that of the injury by the rosy apple aphid except for the dimpling or pitting and russeting, which do not usually occur in the case of injury by aphids.

FIG. 387.—Apples deformed by apple red bugs. Note the dimpled appearance. (*From U. S. D. A. Farmers' Bull.* 1270.)

Trees Attacked.—Apple, pear, haw, and probably others.

Distribution.—States east of the Mississippi River. Most destructive in New York, New England, and southeastern Canad a.

FIG. 388.—Adult of false apple red bug, *Lygidea mendax* Reuter. About three and one-half times natural size. (*From U. S. D. A. Farmers' Bull.* 1270.)

Life History, Appearance, and Habits.—Red bugs pass the winter in the egg stage. These eggs are laid in the bark of branches of the trees in the case of the dark apple red bug,[1] and in the bark lenticels in the case of the light or false apple red bug.[2] They hatch early in the spring. The young nymphs feed at first on the foliage and later on the young apples. They are piercing-sucking insects, and feed entirely on the sap of the leaves or juice of the fruit. Wherever they insert their beaks in the apple, the surrounding tissue becomes hardened and ceases to grow, and the entire fruit is stunted. These two species have essentially the same habits. Upon becoming full-grown, the adults of the dark apple red bug are about ¼ inch long, reddish-black in color and covered on the upper surface with white flattened hairs. In the false red bug (Fig. 388) the head and front part of the body are of an orange color. There is but one

[1] *Heterocordylus malinus* Reuter, Order Hemiptera, Family Miridæ.

[2] *Lygidea mendax* Reuter, Order Hemiptera, Family Miridæ.

generation annually, nearly all of the injury being caused by the young or nymphs, during the first month after the fall of the petals.

Control Measures.—Red bugs can not be controlled by the application of any stomach poison, as they do not feed on the surface of the leaves or the fruit. Where abundant they may be controlled by the use of a contact poison such as 40 per cent nicotine sulfate 1 part to 800 parts of water, or ½ pint to 50 gallons. This should be applied in the cluster-bud spray and again in the calyx spray (see Spray Schedule, p. 586). Nicotine sulfate may be combined with the ordinary-strength lime-sulfur and arsenate of lead, or may be applied alone. In the latter case, it is much more effective if 1 pound of potash fish-oil soap is dissolved in each 25 gallons of the spray mixture. The spray should be applied on warm days by two men working from opposite sides of the tree, as the red bugs are so active that they may escape being hit by a spray applied to one side of the tree at a time. On cool days, the insects will not be feeding in the trees.

References.—*N. Y.* (*Cornell*) *Agr. Exp. Sta. Bulls.* 291, 1911, and 396, 1918; Slingerland and Crosby, "Manual of Fruit Insects," p. 28, 1914; *N. Y.* (*Geneva*) *Agr. Exp. Sta. Bull.* 490, 1921.

Apple Maggot[1]

Importance and Type of Injury.—Apples in the colder sections of the United States are often badly injured by the maggots of medium-sized black, white, and yellow flies. These maggots bore through the flesh of the apple, and are known as the apple maggot, or more commonly as the "railroad worm." Where this insect is abundant, it is one of the most serious pests of apples, especially early varieties. Infested apples have brown, winding galleries running through the flesh. Heavily infested fruit will be reduced to a brown rotten mass filled with yellowish legless maggots, about ¼ inch in length and tapering towards the head. When the fruit is slightly infested, there is no external indication of the presence of the maggots, but when the fruit becomes ripe, the burrows show as dark lines under the skin (Fig. 390). There is a marked difference in the susceptibility to attack by different varieties, the thin-skinned, early maturing varieties being most severely injured.

Plants Attacked.—The apple maggot is a native insect, probably feeding originally on haws. It has been found in wild crabs, is a serious pest of blueberries and feeds to some extent in huckleberries, plums and cherries.

Distribution.—The apple maggot is a northern insect occurring as far west as North and South Dakota, southward and eastward to Arkansas, and Ohio, and throughout the northeastern states and southeastern

[1] *Rhagoletis pomonella* Walsh, Order Diptera, Family Trypetidæ.

Canada. A small variety of this species, breeding in snowberry, has been taken in the western states.

Life History, Appearance, and Habits.—The winter is passed in the pupal stage within a brown puparium about ¼ inch long. These puparia are buried in the soil to a depth of from 2 to 6 inches or more. The adult flies begin emerging about midsummer. They are black in color, with white bands on the abdomen, four on the female and three on the male, and are a little smaller than the house fly. The wings are conspicuously marked with four oblique black bands (Fig. 389). They drink drops of water that have accumulated on the fruit and leaves. The females lay

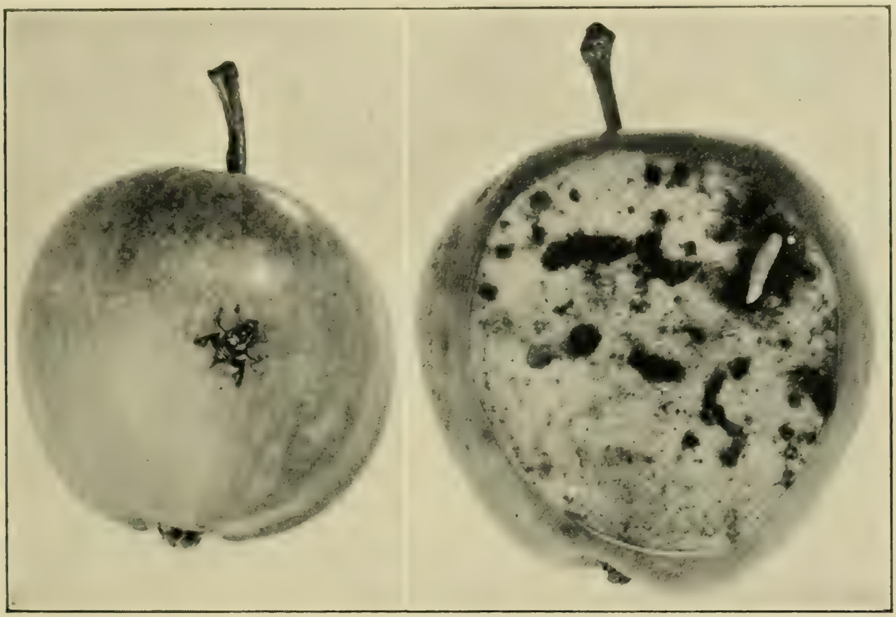


Fig. 389. Fig. 390.

Fig. 389.—Apple maggot, *Rhagoletis pomonella* Walsh; adult on fruit, natural size. (*From Ontario Dept. Agr. Bull.* 271.)

Fig. 390.—Section through an apple infested with the apple maggot, showing a full-grown larva, natural size. (*From Ont. Dept. Agr. Bull.* 271.)

their eggs in punctures in the skin of the apple, made by a sharp ovipositor attached to the tip of the abdomen. Egg laying does not usually take place until 2 or 3 weeks after the flies have emerged. The eggs hatch in from 5 to 10 days, and the maggots develop slowly in the green fruit and do not usually complete their growth until the infested apples have dropped from the tree. After the fruit has fallen, the larvæ leave the apple and enter the ground, where the puparia are formed within which they pupate. In the southern part of the range of the insect, there is a partial second generation, the adults emerging in the early fall.

Control Measures.—The most effective control for the apple maggot is to spray the trees at the time the adults make their appearance in midsummer, using arsenate of lead at the rate of 1 pound to 50 gallons of water. Throughout most of the insect's range, this spray should first be

given during the first week in July, and should be followed by a second, and possibly a third, application, at intervals of two weeks. The flies feeding on the surface of the fruit and foliage are poisoned by the spray. Picking up all early-dropped fruit and feeding it to hogs will destroy many of the larvæ before they have left the apples.

References.—Jour. Agr. Res., Vol. 28, Apr. 5, 1924; *Nova Scotia Dept. Agr. Bull.* 9, 1917; *N. H. Agr. Exp. Sta. Bull.* 171, 1914; *U. S. Dept. Agr. Tech. Bull.* 66, 1928.

Spray Schedule for Apples

In most of the apple growing sections of the north-central United States, the following spray schedule is followed as a part of the regular orchard practice. The grower should follow the spray schedule recommended by the agricultural experiment station of his own state:

I. Dormant Spray.—Applied before the trees come into leaf, or as a delayed dormant spray, when the buds are showing tip green. Applied generally for the control of scale insects and leaf roller.
Materials to be used: Commercial lime-sulfur (33° Bé.) 1 part to 7 parts of water; or lubricating-oil emulsions, 2 per cent oil.

II. The Cluster-bud Spray.—Applied when the fruit buds have separated, but before the petals have opened. This spray is mainly for disease control, but is of importance in the control of some insects.
Materials to be used:

Water	49 gallons
Commercial lime-sulfur	1 gallon
Arsenate of lead	1 to 2 pounds

III. The Petal-fall or Calyx Spray.—The application should be begun when the petals are three-fourths fallen. This is the most important spray for the control of the codling moth.
Materials to be used: Same as for the cluster-bud spray.

IV. The 1-week or 10-day Spray.—Applied 1 week to 10 days after number III. Mainly for disease control, but is of importance in the control of the plum curculio, codling moth, and some other insects.
Materials to be used: Same as for the cluster-bud spray. Or, 3-6-50 Bordeaux mixture, 50 gallons, arsenate of lead, 1 to 2 pounds.

V. The 3-weeks Spray.—Applied 3 weeks later than number III. For the first-generation larvæ of the codling moth and the control of certain diseases.
Materials to be used: Same as for the cluster-bud spray.

VI. Later Sprays.—Later sprays are needed, but the time of applications will vary with the locality and pests to be combated.
Materials to be used: Same as for the cluster-bud spray; or

Water	50 gallons
Hydrated lime	2 to 4 pounds
Arsenate of lead	1 to 2 pounds

B. PEAR INSECTS

FIELD KEY FOR THE IDENTIFICATION OF INSECTS INJURING THE PEAR

1. Dark masses of wet frass protrude from the sides of the fruits or from the blossom end, being forced out from holes which extend through the flesh of the fruit usually

to the core. Pinkish-white, brown-headed worms feeding in these holes. Flat, shining, white eggs on the leaves in the vicinity of fruits or on the skin of the fruit. *Codling moth*, page 587.

2. Fruit and branches specked with small blackish or grayish-brown scales, circular in outline and from very small to a little larger than a pinhead, with a raised, dark-gray, nipple-shaped area in the center. Bright, lemon-yellow, soft-bodied insects lying under the protecting scale. In heavy infestations, bark of twigs and branches completely coated with a gray covering of scales. *San José scale*, page 587.

3. Slender, bronze, shining beetles, about ⅓ inch in length, on the bark of the sunny sides of the pear trees during May and June. Twisting or winding, brown burrows running through the inner bark, indicated by swelling or cracking of the outer bark. Where burrows are numerous, trees are sometimes girdled and killed. *Sinuate pear-tree borer*, page 588.

4. Pear trees with foliage showing a brownish color, blackening or drying up about midsummer. Very small, shining, cicada-like insects, about $\frac{1}{10}$ inch long, under the bark of infested trees during the winter. Minute, orange-yellow eggs on bark at base of fruit spurs in spring. Translucent, yellow, olive, or black, very small, but broad, wingless nymphs, sucking the sap from the stems of leaves, and sometimes from the under surface of the leaf. Sticky drops of nearly colorless liquid on the leaves and fruit, sometimes covered by a black growth of soot-like fungus. *Pear psylla*, page 588.

5. Very minute, elongated, nearly white-bodied, four-legged mites, about $\frac{1}{25}$ inch long, sheltering under the bud scales of trees in winter, and forming reddish-brown, blister-like galls on the undersides of the leaves during the growing season. Galls often so thick as entirely to coat the under surface of the leaves, giving them much the appearance of being infected with some fungus. *Pear-leaf blister mite*, page 590.

6. Buds and young flowers of pear, prune, and some other fruits fail to open, and become brown and blasted in appearance. Very small, black, slender-winged insects feed within the buds or opening flowers. Young fruits shrivel and drop. *Pear thrips*, page 592.

7. Soft, fleshy, dark-green to orange, slimy, slug-like larvæ, up to ½ inch in length, feed on the surface of pear and cherry leaves, skeletonizing the leaves. Most abundant during late spring and again in late summer. In late spring, black and yellow wasp-like insects, about ⅕ inch in length, lay their eggs on the leaves. *Pear slug*, page 616.

Codling Moth

The fruit of the pear is subject to attack by the codling moth, but not to as great an extent as is the apple. The control measures are the same as for the apple (see p. 571), but fewer sprays are required.

San José Scale

Varieties of pears, such as Duchess, Seckel, Bartlett and Bosc, are subject to attack by the San José scale and should be given the same dormant treatment as the apple. Mature Kieffer and Garber pears are seldom seriously injured by San José scale and rarely need to be sprayed for the control of this insect (see p. 539).

Borers

Pears are quite subject to attack by the flat-headed apple-tree borer and some species are also injured by the round-headed apple-tree borer. The control methods for these insects are the same as those given for their control on apple (see pp. 526–529).

Sinuate Pear-tree Borer[1]

Importance and Type of Injury.—Trees infested by this insect have narrow winding burrows in the inner bark and sapwood, the presence of these burrows being indicated by dark lines in the outer bark. If the burrows are numerous the bark will be killed. Trees are sometimes girdled and killed where the insects are abundant.

Trees Attacked.—Pear.

Distribution.—This is a European insect first found in New Jersey in 1894. Its known range in North America is confined to New Jersey and New York.

Life History, Appearance, and Habits.—The winter is passed in the larval stage in burrows in the tree. The larvæ, which are very slender, are of two sizes in winter; the smaller, about 1/2 inch long, in the inner bark, and the larger, about 1 1/2 inches long, in small cells in the sapwood which are plugged at each end with coarse sawdust. The larger larvæ pupate in the early spring and emerge as beetles during the last of May and June. These beetles are very slender, about five times as long as wide, of a purplish-bronze color, and about 1/3 inch long. They are somewhat flattened, and taper to a blunt point at the tail end. The beetles feed on the foliage of the pear and the females, after mating, lay their eggs in cracks in the bark. The grubs on hatching burrow in the bark as above described. The larvæ grow rather slowly, changing to pupæ the second spring after the eggs are laid. There is probably one generation each two years.

Control Measures.—The dead or dying trees, or branches that are very heavily infested, should be cut off and burned during the winter. If the foliage of the pear trees is sprayed heavily with arsenate of lead 2 pounds to 50 gallons of water just about the time the adult beetles emerge, most of them will be killed when they feed on the poisoned leaves. This is the most effective control.

Reference.—Conn. Agr. Exp. Sta. Bull. 266, 1921.

Pear Psylla[2]

Importance and Type of Injury.—In sections where this insect has become established, that is, in the northeastern part of the country, it is one of the most important pests of the pear. The leaves on heavily infested trees turn brown and often drop, the fruit drops prematurely,

[1] *Agrilus sinuatus* (Olivier), Order Coleoptera, Family Buprestidæ.

[2] *Psylla* (*Psyllia*) *pyricola* Förster, Order Homoptera, Family Chermidæ.

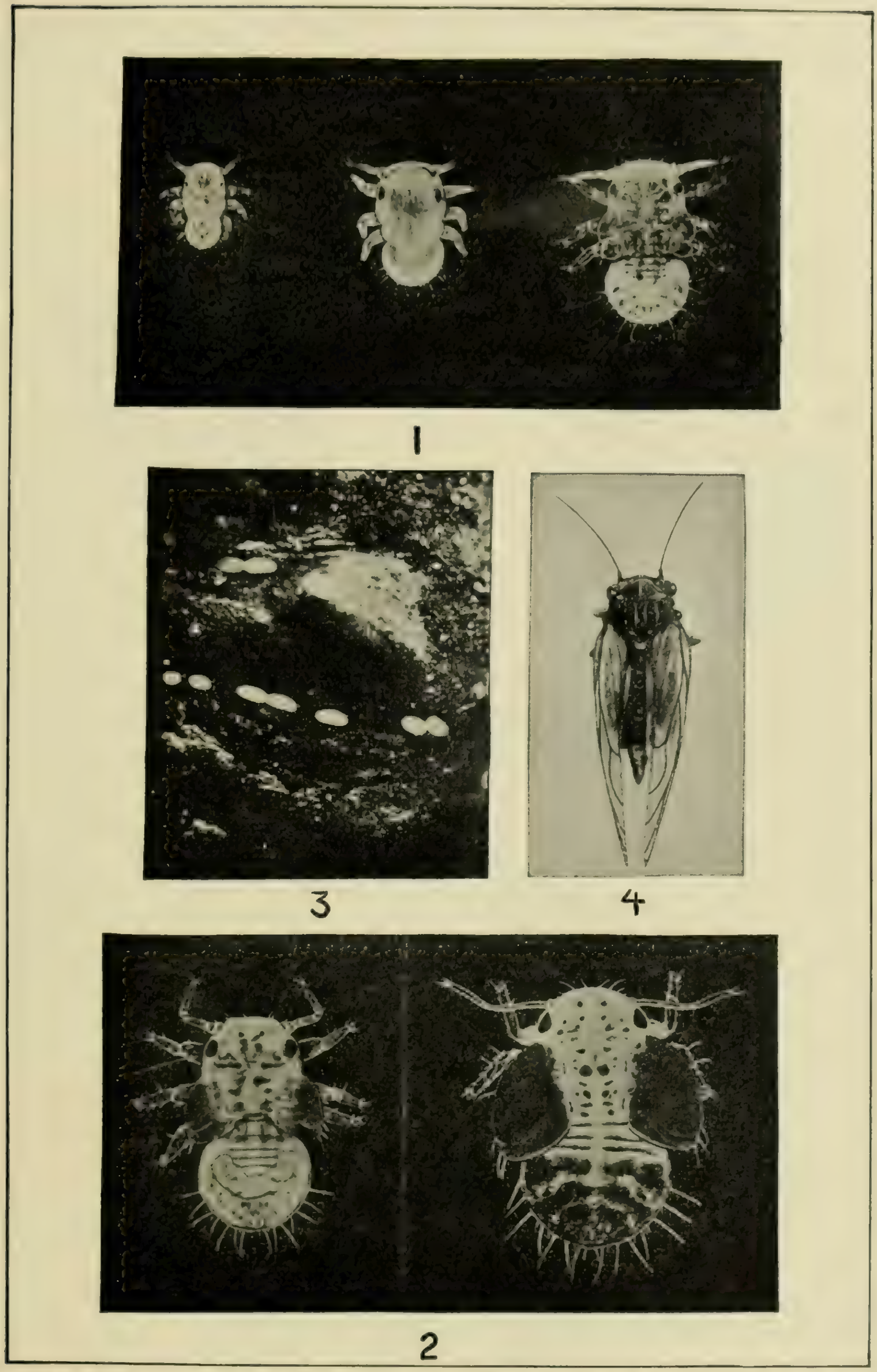


FIG. 391.—The pear psylla, *Psylla pyricola* Förster. 1, first, second and third stage nymphs; 2, fourth and fifth stage nymphs; 3, eggs; 4, winter adult. All much enlarged. (*From N. Y. (Geneva) Agr. Exp. Sta. Bull.* 527.)

or is undersized and of poor quality. Dark, reddish-brown, four-winged, cicada-like insects, about $\frac{1}{10}$ inch in length (Fig. 391, 4), will be found under the bark during the winter; and much smaller, very broad, active, yellow nymphs (Fig. 391, 1, 2) on the fruit and leaves during the growing season. The leaves and fruit of badly infested trees will be covered with honeydew, which in turn is generally coated with a black fungus, later in the season.

Trees Attacked.—Pear.

Distribution.—This insect is of European origin, was brought to Connecticut about 1832, and has spread over the eastern states.

Life History, Appearance, and Habits.—The pear psylla passes the winter as an adult under the bark of the trees or in other sheltered places about the orchard. The adults come out of hibernation early in the spring and the females deposit their pear-shaped, orange-yellow eggs (Fig. 391, 3) in cracks in the bark or about the buds. The eggs are attached by a short stalk and have a thread-like filament projecting from the unattached end. The eggs hatch in 2 weeks to a month and by the time the trees are in full bloom many very small, yellow, wingless nymphs about $\frac{1}{80}$ inch long may be found on the stems and undersides of the leaves, from which they are sucking the sap. These nymphs complete their growth in 1 month, or slightly less. There are from three to five generations each season, the eggs of the later generations being laid on the leaves and stems.

Control Measures.—One of the most effective methods of controlling this insect is to spray the trees very thoroughly with oil emulsions or miscible-oil sprays, applied at the strength found effective for the control of San José scale. The spraying should be done as soon as the trees lose their leaves in the fall, or just before growth starts in the spring. As many of the pyslla are on the small branches and twigs very thorough spraying is necessary to hit the bodies of all the insects. The trees may be thoroughly sprayed with dormant-strength lime-sulfur solution (1 to 9), applied just before the blossom buds open. This spray will prevent the hatching of any eggs that are thoroughly coated with it. Here again the most thorough application is necessary. Very good control has been obtained by summer spraying with Bordeaux mixture (2-3-50) and $\frac{1}{2}$ pint of 40 per cent nicotine sulphate to each 50 gallons. Dusting with strong nicotine dusts has given fair control.

Reference.—*N. Y. (Geneva) Agr. Exp. Sta. Bull.* 387, 1914; and 527, 1925.

Pear-leaf Blister Mite[1]

Importance and Type of Injury.—Brownish blisters appear on the undersides of the pear and apple leaves. The blisters are commonly

[1] *Eriophyes pyri* Pagenstecher, Order Acarina, Family Eriophyidæ.

1/8 inch across, or massed together in such a way as nearly to cover the underside of the leaf surface (Fig. 392). Upon examination with a lens, these blisters will be found swarming with very small, elongated, pale, four-legged mites.

Trees Attacked.—Pear and apple.

Fig. 392.—Pear leaves infested with the pear-leaf blister mite. Reduced. (*From Slingerland and Crosby, "Manual of Fruit Insects," copyright,* 1915, *by the Macmillan Company. Reprinted by permission.*)

Distribution.—General in fruit growing sections of North America. It was introduced into this country about 1870.

Life History, Appearance, and Habits.—The adult mites, which are only about 1/25 inch long (Fig. 393), go through the winter beneath the bud scales. As soon as the foliage has started to come out in the spring,

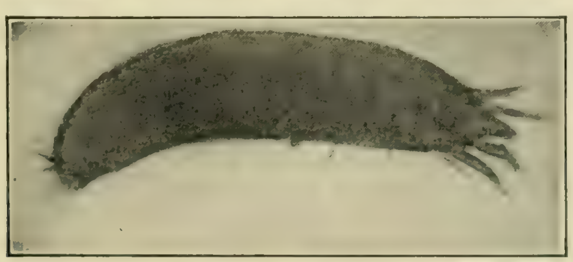


Fig. 393.—A pear-leaf blister mite, *Eriophyes pyri* Pagenstecher. About 250 times natural size. (*From Slingerland and Crosby, "Manual of Fruit Insects," copyright,* 1915, *by the Macmillan Company. Reprinted by permission.*)

they become active and start feeding on the undersides of the leaves, causing the brownish blisters in which the eggs are laid and the young develop. There are a number of generations each year. The creatures may also attack the fruit, causing it to be dwarfed or to drop when the mites are numerous.

Control Measures.—Pear-leaf blister mites are readily controlled by winter spraying with lime-sulfur, or miscible oil, at the same strength as for San José scale.

References.—*U. S. Dept. Agr. Farmers' Bull.* 722, 1916; *N. Y.* (*Geneva*) *Agr. Exp. Sta. Bull.* 306, 1908.

Pear Thrips[1]

Importance and Type of Injury.—Pear thrips attack the buds of fruit trees very early in the spring, before the buds open, causing them to shrivel and turn brown. The female thrips also injure young fruits by depositing their eggs in the stems of the blossoms. These egg punctures cause the fruit to drop. Heavily infested orchards appear as though injured by fire. In some sections the insect is very important.

Distribution.—This insect is an imported species and was first found in California in 1904. It now occurs along the Pacific coast, in California, Oregon, and British Columbia. In the eastern part of the country, it is recorded from New York, Pennsylvania, and Maryland.

Plants Attacked.—The insect is primarily a pest of pear, and attacks also apple, apricot, cherry, grape, peach, plum, prune, and several other fruit trees, as well as poplar, maple, shadberry, willow, currant, and several shrubs and weeds.

Life History, Appearance, and Habits.—The winter is passed from 5 to 7 inches deep in the soil, in small cells. The insects are in the newly formed adult stage. They remain in these cells until early spring, appearing on the trees in New York about the first of April and in California in February. The adults are very active, working their slender bodies in between the bud scales and feeding upon the swelling buds. These adults are about $\frac{1}{20}$ inch long. The females soon begin laying their eggs in the fruit stems, midribs, and stems of leaves. The egg-laying period extends over about 3 weeks. The young nymphs begin hatching in 2 weeks and feed in large numbers within the opening fruit buds. The young are white in color in contrast with the black adults. The young become full grown in about 4 weeks, and, still in the nymphal stage, they drop to the ground, which they enter. There they form the cells in which they pass the summer and hibernate during the winter (see Fig. 108, p. 185).

Control.—The best method of controlling these insects is to spray thoroughly with a miscible-oil or lubricating-oil emulsion at a strength of 2 per cent oil, plus nicotine at the rate of 1 pint to 100 gallons of water. This spray should be applied as soon as the adult thrips appear on the buds. The time of their appearance will vary according to the locality and season, so that one will have to keep watching the trees in order to know the best time for applying this spray. Where thrips are abundant,

[1] *Tæniothrips inconsequens* Uzel, Order Thysanoptera, Family Thripidæ.

a second application of the same materials should be made at the cluster-bud stage of the fruit. In applying an oil spray at this stage, care must be taken to use an oil which is not injurious to the foliage. Serious infestations can be greatly reduced by thorough, deep cultivation of the orchard in the late summer and early fall, if this can be done without injury to the trees.

References.—*U. S. Dept. Agr. Bur. of Entomol. Bull.* 68, pp. 1–16, 1909; *N. Y. (Geneva) Agr. Exp. Sta. Bull.* 484, 1921.

C. QUINCE INSECTS

FIELD KEY FOR THE IDENTIFICATION OF INSECTS INJURING THE QUINCE

1. Grayish scales adhering to the bark and fruit (see Field Key for the Identification of Insects Injuring the Apple, number *C*, 1). *San José scale*, page 539.

2. Worms feeding in, and boring holes through the fruit (see Field Key for the Identification of Insects Injuring the Apple, number *E*, 1). *Codling moth*, page 568.

3. Pinkish to creamy-white, short-legged worms with brown heads, up to ½ inch long, boring in the twigs, causing them to wilt, and also in the fruit. Entrance holes of worms often through the stem, not showing on the outside of the fruit. *Oriental fruit moth*, page 608.

4. Irregular cavities eaten in the flesh of the quince with very small openings through the skin. White, legless grubs feeding in the fruit of the quince during early summer, but seldom causing the fruit to drop. Grayish-brown, rather broad-shouldered snout beetles, the snout about one-third as long as the body, feeding on the flesh of the fruit. Injured fruit becomes deformed and knotty. *Quince curculio*, page 593.

FIG. 394.—The quince curculio, *Conotrachelus cratægi* Walsh; adult, natural size and enlarged. (*From Slingerland, N. Y. (Cornell) Agr. Exp. Sta. Bull.* 148.)

Apple Insects That Injure the Quince

The quince is often infested with San José scale (see p. 539). It is particularly subject to injury by the round-headed apple-tree borer (see p. 527), which seems to prefer the quince above any of the other fruit trees. The fruit is attacked by the codling moth (see p. 568), and the leaves by several of the insects common on apple.

Quince Curculio[1]

The most important insect which confines its attack to the quince is the quince curculio. This curculio differs slightly from the apple and plum curculios in that it goes through the winter in the grub stage in the soil. The adult (Fig. 394) is a broad-

[1] *Conotrachelus cratægi* Walsh, Order Coleoptera, Family Curculionidæ.

shouldered snout beetle grayish-brown in color, without humps on the back.

Control Measures.—Summer cultivation of the orchard is of no value in combating this insect, since it does not enter the soil until late summer. As the grubs leave the fruit before it drops, picking up the dropped quinces cannot be practiced as a control measure.

Thorough spraying with arsenate of lead and lime, 2 pounds of each to 50 gallons of water, is the most effective method of keeping down this insect. The application should be made at approximately the same stage of development of the quince as for the plum curculio on apple (see p. 580).

References.—*N. Y. (Cornell) Agr. Exp. Sta. Bull.* 148, 1898; *N. Y. State Dept. Agr. Bull.* 116, 1919.

D. PEACH INSECTS

FIELD KEY FOR THE IDENTIFICATION OF INSECTS INJURING THE PEACH

A. Insects that burrow in the trunk and branches:

1. Masses of gum, mixed with brown sawdust-like bits of frass and bark, exuding from around the base of the trunk. White caterpillars, with brown heads, up to 1 inch long, burrowing in the bark from 8 or 10 inches above, to 3 or 4 inches below, the surface of the soil. Brown tough-skinned pupa-cases protruding from the gummy masses about the base of the trunk during the latter part of the summer and early fall. Black and yellow wasplike moths flying rapidly, in daytime, about the base of the trunk, in late summer or early fall. *Peach tree borer,* page 595.

2. Masses of gum containing brown sawdust, exuding from the upper part of the trunk and branches of the peach, most frequently from forks of limbs. White caterpillars with brown heads, up to a little over $\frac{3}{4}$ inch in length, working in the bark under masses of gum. Metallic, blue-black, yellow-marked, wasp-like moths flying rapidly about the trees after midsummer. *Lesser peach tree borer,* page 599.

3. Very small, inconspicuous, silk cocoons closely attached to the larger branches and the trunk of the tree during the winter. Brown worms with black heads, from $\frac{1}{16}$ to $\frac{1}{8}$ inch in length, inside these cocoons. Small cavities eaten into the ends of the new growth of peach shoots in the spring, causing them to wilt and die back. Small masses of gum exude from injured twigs. Occasionally the small brown worms will be found in the peach fruits. *Peach twig borer,* page 601.

4. Pinkish to creamy white, short-legged worms with brown heads, the largest $\frac{1}{2}$ inch long, bore in the twigs of peach, causing them to wilt. Injury is similar to *A*, 3. *Oriental fruit moth,* page 608.

5. Small bits of gum exuding from many points along the trunk and branches of peach. Galleries about the size of a pencil lead and a little over an inch long, with sawdust-filled burrows radiating from them, in the inner bark of the tree. Brownish, or brownish-black, blunt-ended beetles, $\frac{1}{16}$ inch long, are found boring the galleries in the inner bark, or crawling over the bark of the tree. *Shot-hole borer* and *peach-tree bark beetle,* page 602.

B. Motionless insects found on the bark of trunk and branches, and on leaves:

1. Round, flattened, grayish scale insects, about $\frac{1}{16}$ inch across, closely adhering to the bark of trees, often with reddened areas of bark about the point where the insects are attached. Lemon-yellow, sack-like, sucking insects sheltered under the waxy scales. *San José scale,* page 603.

2. Peach twigs, particularly on the undersides, nearly covered with sharply convex, brownish scales, about 1/12 inch in diameter, of a general dark-brown color, with some black lines, particularly about the margins. In summer, fruit and leaves of infested branches coated with honeydew or masses of sooty, black fungus. *Terrapin scale*, page 603.

C. Insects that attack the fruit:

1. Crescent-shaped punctures, or slits, with a small hole often cut at the inside of apex of the crescent, on the young peach fruit for the first 2 or 3 weeks after the blooming period. Fat-bodied, brown-headed, white, footless grubs feeding in the flesh of the peach, causing irregular greenish areas on the surface of the fruit and black cavities within the fruit. Many of the grub-infested fruits drop when less than one-fourth grown. Dark-brown snout beetles about 1/8 inch long, with grayish-white patches on the back of the wing covers, feeding and laying eggs on peach fruits for a few weeks after the fruit has set, and feeding again during the latter part of the summer. *Plum curculio*, page 604.

2. Robust, metallic-green to greenish-bronze beetles, a little larger than a common potato beetle, feeding on the fruit of the peach. The abdomen of the insect projects back from the wing covers, and is marked by two conspicuous white spots. The injured fruit appears to have been gouged or partly peeled; sometimes where the beetles are numerous, the entire skin is eaten off. *Japanese beetle*, page 605.

3. Large, somewhat flattened, dark-green beetles up to 1 inch in length, with a brownish-yellow tinge to the wing covers and thorax, feeding on the fruit of the peach, and also on the foliage, during July and August. Fruit scored somewhat as in *C*, 2. Beetles drop to the ground when the trees are shaken in the daytime. Feed mainly at night. *Green June beetle*, page 607.

4. Pinkish to creamy-white short-legged worms, with brown heads, up to 1/2 inch long, bore in the fruits of the peach. Entrance holes of worms often through the stem, not showing on the outside of the fruit. Gray moths with chocolate-brown markings on the wings, about 1/4 inch long, flying about the trees at dusk, or resting on the trunk. *Oriental fruit moth*, page 608.

5. Tan-colored moths, with a purplish tinge and a small, oval, dark spot near the middle of each front wing, distinctly triangular in outline and about 7/8 inch long, suck the juice from cracks or from small punctures that they make in ripening fruits. Feed on peach, grape, apple, and other fruits. Adult of *cotton leaf worm*, page 416.

D. Sap-sucking insects that attack the leaves or twigs:

1. Black shiny eggs on the tips of twigs and in cracks in the bark of larger branches of peach during the winter. Pale-greenish or black aphids sucking the sap of the newly formed fruit, leaves, and young twigs. Leaves on infested trees curl and turn yellow. Insects sometimes so numerous as to cover completely the twigs and foliage. *Green peach aphid*, or *black peach aphid*, page 610.

2. Young peach trees in the orchards, and particularly trees in the nursery row, with the terminal growth and some of the laterals dying back, but not containing borers. Coppery-brown bugs, with oval bodies, somewhat triangular in front and about 1/4 inch long by half as wide, feeding on the terminals, twigs, foliage, and peach fruits. Body of the bugs is somewhat spotted and flecked with yellow and dark brown. Bugs fly readily when approached. *Tarnished plant bug*, page 611.

Peach Tree Borer[1]

Importance and Type of Injury.—The most important insect enemy of the peach is the peach tree borer Nearly everyone who has tried to

[1] *Ægeria exitiosa* Say, Order Lepidoptera, Family Ægeriidæ.

grow peaches, in either a commercial orchard, a farm orchard, or a back yard, is familiar with the work of this insect. Masses of gum exude from around the base of the trunk from about a foot above, to 2 or 3 inches below the surface of the soil, with bits of brownish frass or sawdust, mixed with the gum (Fig. 395). White worms with brown heads will be found burrowing in the bark of the peach trunk from 2 or 3 inches below the surface of the ground, to 10 inches above. Deadened areas in the bark, where these worms have eaten out the living tissue, in many cases causing the death of the tree.

FIG. 395.—Work of a single peach tree borer, natural size; *wb*, burrow of borer; *g*, mass of gum; *p*, pupa projecting from its cocoon preceding emergence of moth. (*Reprinted from "Insect Pests of Farm, Garden and Orchard," by Sanderson and Peairs, published by John Wiley & Sons, Inc., after Slingerland.*)

Trees Attacked.—Peach, wild and cultivated cherry, plum, prune, nectarine, apricot, and certain ornamental shrubs of the genus *Prunus.*

Distribution.—All sections of the United States and Canada westward to Arizona, Utah, Oregon, and British Columbia.

Life History, Appearance, and Habits.—This insect always passes the winter in the worm or larval stage. These worms (Fig. 396) vary greatly in size, some being over ½ inch in length, while others are very small, in some cases not over ⅛ inch long. The difference in the size of the worms comes from the fact that the eggs are laid over a considerable period of time. In the spring of the year, the worm becomes active as soon as the soil is sufficiently warm. The larger ones will complete their growth by the middle or latter part of May and will be found under the bark close to the ground. They are then about 1 inch in length, whitish, with a dark-brown head and plate behind the head. They change in closely spun, silken, dirt-and-gum-covered cocoons on the surface of their burrows or in the soil, to the brown pupal stage. Just before the moth emerges, the pupa forces its way out of the cocoon and the empty pupal skin generally remains protruding from the cocoon. In the latitude of southern Illinois, the first adults begin to appear in July and emergence continues until the latter part of September or possibly in a few cases into October, the greatest number coming out during August. The female insect is a blue-black moth having clear hind wings, with an orange cross-band on the abdomen (Fig. 397). When in flight the moths closely resemble some of the larger wasps, for which they are frequently mistaken.

The male has both wings nearly clear and several narrow yellow bands across the abdomen. The females lay their eggs mostly on the trunks of the trees or in cracks in the soil within a few inches of the trunk. They

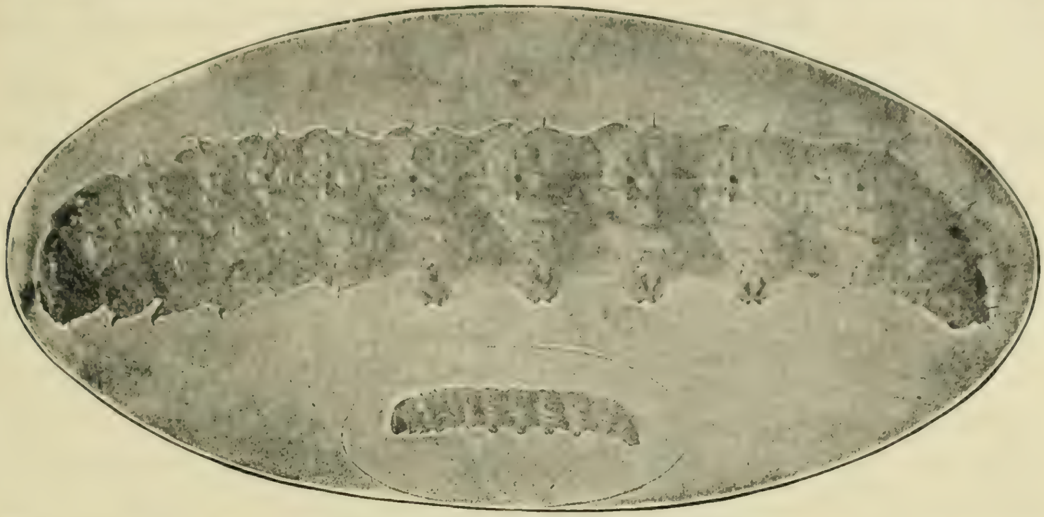


Fig. 396.—Peach tree borer larva, natural size and three and one-half times enlarged. (*Reprinted from "Insect Pests of Farm, Garden, and Orchard" by Sanderson and Peairs, published by John Wiley & Sons, Inc., after Slingerland.*)

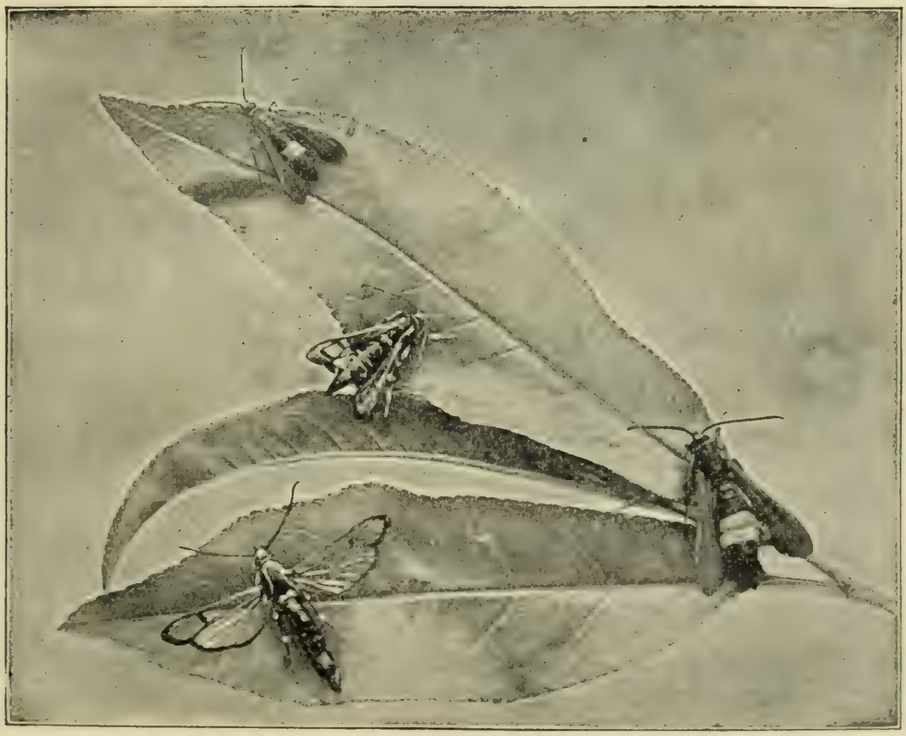


Fig. 397.—Peach tree borer, *Ægeria exitiosa* Say; adults, natural size. The ones at center and lower left are males, the other two females. Natural size. (*From Sanderson and Jackson, "Elementary Entomology," after Slingerland.*)

are seemingly attracted to trees which previously have been infested by the borer, or to those to which some mechanical injury has occurred. Upon hatching from the eggs, the worms work their way into the bark of

the tree and feed during the late summer or early fall in the outer layers of the bark, penetrating deeper into the bark as they become larger. Where the eggs are laid over a period of several months, it is easy to understand the great variation in the size of the larvæ found in the bark in the fall. There is, as a rule, one generation each year.

Control Measures.—While this insect, if not combatted, is almost sure to kill peach trees within a few seasons, we are fortunate in having a control measure which, if properly applied, is nearly 100 per cent effective. This control method consists of placing a small amount of the crystals of paradichlorobenzene, generally called "P.D.B." ("painless death to borers"), on the surface of the soil around the trunk of the tree during the fall (Fig. 398). This method, which has come into general use since about 1920, is now practiced in most of the commercial peach orchards in the United States. The amount of P.D.B. to be applied will vary with the size of the tree. The following rules should be strictly observed in

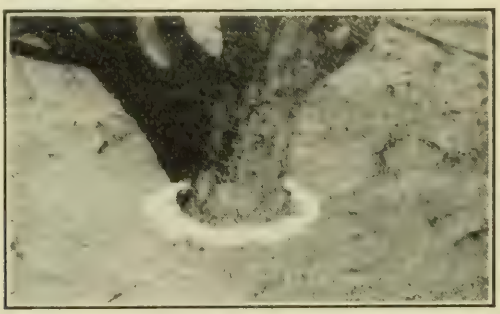


FIG. 398.—A ring of paradichlorobenzene properly placed about the trunk of a peach tree to kill peach tree borers. The ground has been cleared of trash before applying the chemical. Soil will be placed over the ring to confine the fumes. (*From Ill. State Nat. Hist. Sur.*)

using this chemical. For trees under 3 years of age, use ½ ounce per tree, for trees from 3 to 6 years old, ¾ ounce, and for older trees from 1 to 1½ ounces, depending on the diameter of the trunk at the surface of the ground. Apply the crystals in a ring completely encircling the trunk, not closer to the bark than 1 inch, nor at a greater distance than 3 inches. Cover the crystals with several shovelfuls of earth to confine the P.D.B. gas. Do not apply the treatment during the summer, as the borers are not then in the tree; nor in the late fall, when the soil temperature is likely to be below 60° F. for the first 2 weeks after the material is applied. The crystals applied in warm soil quickly volatilize into a heavy gas which penetrates through the soil crevices and into the burrows of the borers and kills them. The best dates for applying paradichlorobenzene can be obtained from entomologists of the state experiment stations. In the latitude of southern Georgia the best dates for making these applications will usually be between Oct. 15 and Oct. 20; in central Georgia, between Oct. 10 and Oct. 15; in northern Georgia, between Sept. 25 and Oct. 5; in the latitude of southern New Jersey, Oct. 1 to Oct. 10;

in northern New Jersey, Sept. 20 to Oct. 1; in southern Illinois, Sept. 25 to Oct. 2; and in northern Illinois, Sept. 20 to Oct. 20.

Spring treatments are not recommended, although if no treatment has been given in the fall, it is in some cases advisable to apply the material in the spring. The treatment will not be effective if given before the soil temperature has reached an average of about 60° F.; by this time the young borers have been actively at work in the bark for several weeks, and will have caused very serious damage. In the East and South, there has been some injury from this treatment applied to young trees, and there it is recommended that the soil be removed from around the tree about 6 weeks after treatment. In any case, the mounds of earth should be leveled before July in order not to force the moths to lay their eggs high up on the trunk.

The borers may be dug out by the use of a sharp knife, or probed out with a flexible wire, first removing the soil from around the base of the tree, to a depth of about 3 inches. This method is slow and laborious and it is not possible in most cases to get all the borers.

References.—N. J. Agr. Exp. Sta. Bull. 391, 1922; *U. S. Dept. Agr. Dept. Bulls.* 796, 1919, and 1169, 1923; *Ohio Agr. Exp. Sta. Bull.* 329, 1928; *U. S. Dept. Agr. Tech. Bull.*, 58, 1928.

Lesser Peach Tree Borer[1]

Importance and Type of Injury.—Masses of gum exude from the trunk and branches of the peach tree where injury has occurred. Frequently these masses of exuding gum will be found in the forks, especially where the forks have split, and around wounds in the bark (Fig. 399). White worms with brown heads will be found working in the inner bark. Bits of brownish castings and sawdust-like material are mixed with the masses of gum. The larvæ very closely resemble those of the peach tree borer, but their attacks may usually be distinguished in the orchard by the fact that they attack the upper part of the trunk and the larger branches.

Trees Attacked.—Peach, plum, cherry, wild plum, wild cherry, Juneberry, and possibly some others.

Distribution.—Peach-growing sections of the United States, except the western states; most abundant in the South.

Life History, Appearance, and Habits.—The lesser peach tree borer passes the winter in the inner bark of the peach tree in the form of partly grown larvæ. These larvæ vary in size from 1/4 inch to nearly 1 inch in length. They start to feed very early in the spring, the larger individuals completing their growth by late April and the smaller ones by the last of June. They pupate in cocoons inside the burrows, but always come close to the surface of the bark, leaving the exit of the burrow covered by a thin silken web. Just before the moths emerge, the pupæ push themselves

[1] *Synanthedon pictipes* Grote and Robinson, Order Lepidoptera, Family Ægeriidæ.

out of the cocoon and partly out of their burrows. Emergence of the moths takes place during May and June. The moths are clear-winged, of a metallic, blue-black color with pale-yellow markings on the abdomen. They are extremely active and dart about with great rapidity. Their general appearance is much like that of some of the larger wasps. The female lays her eggs in cracks and crevices in the bark, usually around the crotch of the tree, or wounds in the bark. The eggs hatch in about 10 days after they are deposited, and the larvæ work their way into the bark. A partial second generation occurs over most of the north central states and probably nearly a full second generation in the South.

Fig. 399.—Work of the lesser peach tree borer, *Synanthedon pictipes* Grote and Robinson. (*From Ohio Agr. Exp. Sta. Bull.* 307.)

Control Measures.—A very large number of sprays, paints, and washes have been tried in an attempt to control this insect, or to repel the females so that they would not deposit their eggs on the bark. None of these have given sufficient protection to warrant the expense of using them. Paradichlorobenzene cannot be successfully used against this species because it attacks the tree above the level of the soil.

The lesser peach tree borer is of little importance in well-sprayed, cultivated, and properly fertilized orchards. The best method of controlling this insect is to keep the trees in a vigorous, healthy condition, and avoid, so far as possible, injuries to the bark and crotches of the tree.

The worms may be dug out by hand, as recommended under the peach tree borer.

Reference.—Ohio Agr. Exp. Sta. Bull. 307, 1917.

Peach Twig Borer[1]

Importance and Type of Injury.—In unsprayed or neglected orchards, the peach twig borer is of considerable importance. Small brown worms may be found working inside the twigs and new growth, and occasionally in the fruits. The twigs die back and small masses of gum exude from them.

Trees Attacked.—Peach, plum, and apricot.

Distribution.—General in peach-growing sections, most serious on the Pacific Coast.

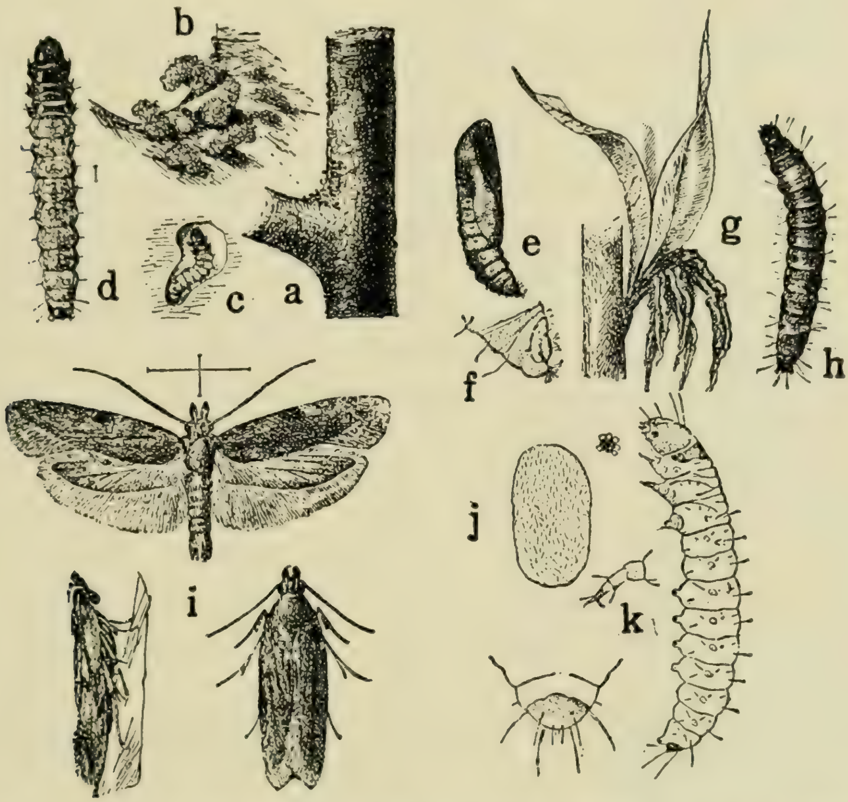


Fig. 400.—The peach twig borer, *Anarsia lineatella* Zeller. *a*, *b*, *c*, *d*, larva and its winter nests; *e*, *f*, pupa with detail of posterior end; *g*, new shoot of peach withering from attack of larvæ; *h*, larva enlarged; *i*, adult moths; *j*, egg greatly enlarged; *k*, larva, side view and details of structure. The lines show natural size. (*From U. S. D. A. Bur. of Entom. Bull.* 10, *n.s.*)

Life History, Appearance, and Habits.—This insect passes the winter as a partly grown, brown caterpillar, with a black head, from 1/8 to 1/16 inch in length, hidden in a silken cocoon closely attached to the bark of trunk and branches (Fig. 400, *a*, *b*, *c*). About the time the peach leaves appear, the larvæ leave their winter nests and start boring in the ends of the tender new growth, causing a wilting and dying back of the twigs (*g*) in which they are working. A larva may feed in more than one twig before it completes its growth. Upon becoming full-grown, the larvæ are about 1/2 inch in length. They then spin cocoons on the larger branches or trunk. Here they change into small moths, gray in color, with a wing-spread of about 1/3 to 1/2 inch (*i*). The moths mate, and the female lays her eggs on the twigs. Another generation of the

[1] *Anarsia lineatella* Zeller, Order Lepidoptera, Family Gelechiidæ.

worms soon hatches and feeds in the same manner as those which have gone through the winter. There are probably from one to four generations of the insect in the United States each season, the larger number occurring in the South.

Control Measures.—Damage by this insect is confined, as previously stated, largely to unsprayed orchards. The most effective control measure in the central states is a dormant spray with lime-sulfur or oil emulsion, such as is used for controlling the San José scale. This spray kills the overwintering larvæ in their cocoons. Where such treatments are regularly given practically no damage from the peach twig borer occurs. In some of the western states it has been found that the addition of 3 pounds of arsenate of lead to 50 gallons of lime-sulfur, 1 to 10, applied as near the pink stage of the buds as possible, gives good control.

References.—*Jour. Econ. Entomol.*, Vol. 15, p. 395, 1922; *Colo. Agr. Exp. Sta. Bull.* 119, 1907; *Calif. Agr. Exp. Sta. Bull.* 355, 1923.

Shot-hole Borer[1] and Peach-tree Bark Beetle[2]

Importance and Type of Injury.—These two important species of bark beetles attack the trunk and branches of the peach. They are so similar in their habits that a separate description will not be given. The shot-hole borer, or fruit-tree bark beetle, is further discussed on pages 530 and 670. Small beads of gum will be found exuding from points on the bark of the trunk and branches of the peach; also small holes in the bark, about the size of a No. 6 shot. Galleries of borers are found in the inner bark radiating from a main or parent gallery and terminating in small round exit holes through the bark.

Trees Attacked.—The shot-hole borer attacks peach, cherry, plum, apple, and other fruit and shade trees. The peach-tree bark beetle attacks cherry, and other stone fruits, but *not* the pome fruits.

Distribution.—The peach-tree bark beetle is most abundant in the eastern half of the United States. The shot-hole borer occurs throughout the country.

Life History, Appearance, and Habits.—These insects are small, brownish or blackish beetles about $\frac{1}{10}$ inch or less in length. The peach-tree bark beetle winters in the adult stage, either in its pupal cells in dead or dying wood or in special hibernating cells cut in the bark of healthy trees. The shot-hole borer passes the winter in the form of a small, pinkish-white legless grub in the inner bark of the tree. These grubs transform to beetles in their burrows and emerge in the late spring. Both species are good fliers, and are seemingly attracted to trees that are in a poor condition or those having dying branches. The parent beetles excavate a burrow in the inner bark of such trees, and along the sides of this the female lays her eggs. The parent gallery of the shot-hole borer (Fig. 340) generally runs the long way of the branch. That of the peach-tree bark beetle (Fig. 401) generally runs crosswise and forks to form a "Y" at one end of the gallery. The grubs hatching from these eggs work out through

[1] *Scolytus rugulosis* Ratzeburg, Order Coleoptera, Family Scolytidæ.

[2] *Phthorophlœus liminaris* (Harris), Order Coleoptera, Family Scolytidæ.

the inner bark for a distance of 2 to 3 inches, gradually enlarging their burrows as they go. The larval burrows of the peach-tree bark beetle follow mostly the grain of the wood, while the larval burrows of the shot-hole borer run chiefly across the grain. Upon becoming full-grown, they change to beetles and emerge through small holes which they cut in the bark. There are at least two generations of these insects in the latitude of central Illinois, and a partial third farther south.

Control Measures.—As the insects are attracted mainly to unhealthy or injured trees, the best control measure is to keep the trees in a vigorous condition during the summer, either by cultivation, or by fertilizing with nitrogenous fertilizers. All peach prunings and dying or diseased trees in or around the orchard should be removed and burned during the winter. There is no method of spraying which has been found effective for these insects which will not also injure the tree.

References.—U. S. Dept. Agr. Farmers' Bull. 763, 1916; *Ohio Agr. Exp. Sta. Bull.* 264, 1913.

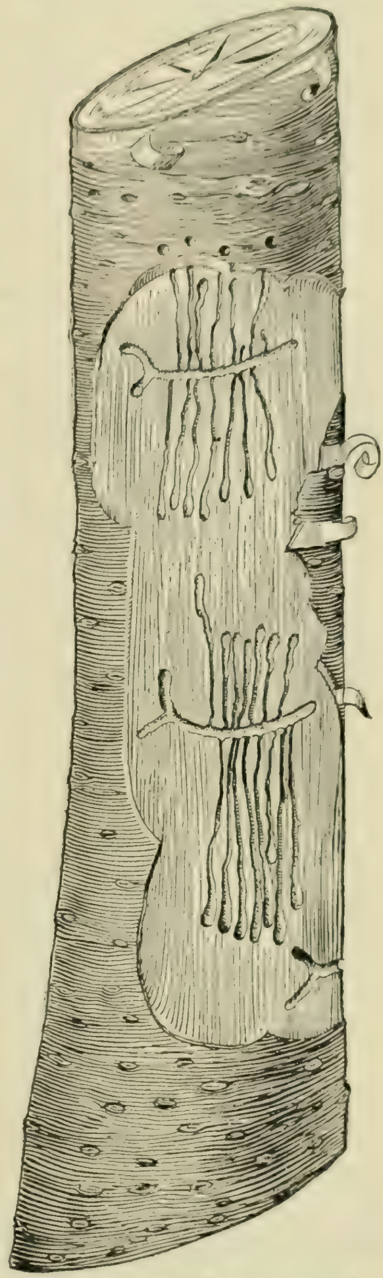


FIG. 401.—Work of the peach-tree bark beetle, *Phthorophlœus liminaris* (Harris), in wood of peach tree, showing parent galleries, larval galleries and exit holes. (*From U. S. D. A. Farmers' Bull.* 763.)

SAN JOSÉ SCALE

The San José scale is fully as serious a pest of the peach as of the apple. The life history of this insect on the peach is practically the same as on the apple and the control measures are the same (see p. 542). Oil sprays should be used with caution on peach during the active growing season.

TERRAPIN SCALE[1]

Importance and Type of Injury.—During the winter the undersides of peach twigs are sometimes found nearly covered with shiny convex, brownish scales about $\frac{1}{12}$ inch in diameter (Fig. 403). In the summer, the fruit will be covered with masses of honeydew on which a sooty black fungus grows.

Plants Attacked.—All the common fruits, and many shade trees and shrubs.

Distribution.—Eastern and southern United States.

Life History, Appearance, and Habits.—The scale passes the winter as fertilized females closely adhering to the bark of the twigs (Fig. 402). These vary somewhat in

[1] *Eulecanium nigrofasciatum* Pergande, Order Homoptera, Family Coccidæ.

color but are of a general dark brown, with some black lines about the margins of the scale. The scale margins are also generally somewhat crinkled. They resume feeding early in the spring and by the last of May or early June the female, which is then about $\frac{1}{7}$ inch in diameter, begins giving birth to living young. These accumulate in a domeshaped cavity underneath her body, and a day or two after birth the tiny nymphs, which are oval, white and with well-developed legs and antennæ, crawl from under the dead female's body and out to the undersides of the leaves. Here they insert their beaks along the larger veins and feed by sucking the sap. After about a month on the leaves, the females migrate back to the twigs, and a week or two later the winged males find them and mating occurs. The males die in midsummer, but the females continue to feed until cold weather, hibernate through the winter, feed again in spring as stated above, and finally die during the following summer. There is but one generation a year.

Fig. 402.—Mature female of the terrapin scale, *Eulecanium nigrofasciatum* Pergande; (*a*) ventral, (*b*) dorsal and (*c*) lateral views. About eight times natural size. (*From U. S. D. A. Dept. Bull.* 351.)

Control Measures.—This scale cannot be satisfactorily controlled by applications of lime-sulfur. Control has been obtained from a 2 per cent lubricating-oil emulsion; or the commercial miscible oils or oil emulsions, used at the strengths recommended by the manufacturers for the control of San José scale.

Reference.—U. S. Dept. Agr. Dept. Bull. 351, 1916.

Plum Curculio[1]

The plum curculio, which has been described under apple insects (see p. 577), is one of the most serious insect pests of the fruit of the peach. The adults damage the fruits by their feeding and egg-laying punctures and the larvæ tunnel through the fruit, feeding on the pulp. Infested fruits generally drop. The plum curculio is also one of the main agencies in spreading the brown rot of the peach.

Fig. 403.—Terrapin scale on peach twigs during winter, about natural size. (*From U. S. D. A. Dept. Bull.* 351.)

[1] *Conotrachelus nenuphar* (Herbst), Order Coleoptera, Family Curculionidæ.

Control.—The method of control is, in general, the same as that given for the insect on the apple. In peach orchards which have been badly infested, it is often advisable to gather the peach "drops" during May and the first part of June. The orchard should be gone over every few days, if possible, and the dropped peaches gathered and burned or buried to a depth of at least 2 feet. For the control of this insect, general orchard sanitation is as important in peach orchards as in apple orchards. It is also important that the orchard be kept well cultivated during the late spring and early summer, to destroy the larvæ and pupæ of the curculio in their cells in the earth.

The peach tree is more sensitive to arsenical injury than apple, and care must be used in applying these poisons. The first spray should be given about 10 days after the peach has bloomed, or as soon as the brown skin or shuck is pushed off by the forming fruit. Powdered arsenate of lead 1 pound, and 2 pounds of fresh hydrated lime should be used to each 50 gallons of spray material. The second spray should be given 3 weeks later. A third and fourth spray are usually necessary on the later maturing varieties. The last spray for curculio should be applied about a month before the fruit is ripe. In badly infested peach orchards, it may be of advantage to apply an additional spray immediately after the fall of the petals, but this is not generally recommended. Recent experiments have shown that the curculio may be controlled by dusting, using a dust consisting of 10 pounds of arsenate of lead, 10 to 20 pounds of hydrated lime, and 70 to 80 pounds of dusting sulfur. The applications should be made at the same time as recommended for sprays, with possibly one or two additional applications. The airplane is being used to apply the dusts in sections where there are many large peach orchards. (See Fig. 185.)

Japanese Beetle[1]

Importance and Type of Injury.—Metallic green or greenish-bronze beetles, a little larger than the common potato beetle, with two prominent, and several smaller, white spots near the tip of the abdomen, feed on the surface of the fruit and leaves of the peach. The fruit may be partly peeled and gouged in irregular shallow patches, or nearly devoured. The leaves are skeletonized on many trees and plants. Grass is sometimes killed by the feeding of the larvæ on the roots. Where the beetle has become established in the eastern United States, it is so abundant as to cause serious injury to tree fruits and also to many field crops and some truck crops on which it feeds.

Plants Attacked.—The adult beetles feed on the foliage of many plants, including most fruits and vegetables, and also on the fruits of plum, apple, peach, pear, and other trees. Smartweed is a favorite food.

[1] *Popillia japonica* Newman, Order Coleoptera, Family Scarabæidæ.

Distribution.—This insect is well established in a large area in the eastern United States, including parts of the states of Pennsylvania, New Jersey, Delaware, New York, Connecticut, Maryland, and the District of Columbia, and it is spreading rapidly. The insect was imported into New Jersey from Japan, on the roots of nursery stock, about 1916.

Life History, Appearance, and Habits.—The winter is passed as a grub about ½ inch long, buried in the soil (Fig. 404). Growth is completed during June, and the adults emerge in greatest numbers in July. The female beetles lay their eggs in the soil, the grubs feeding mainly

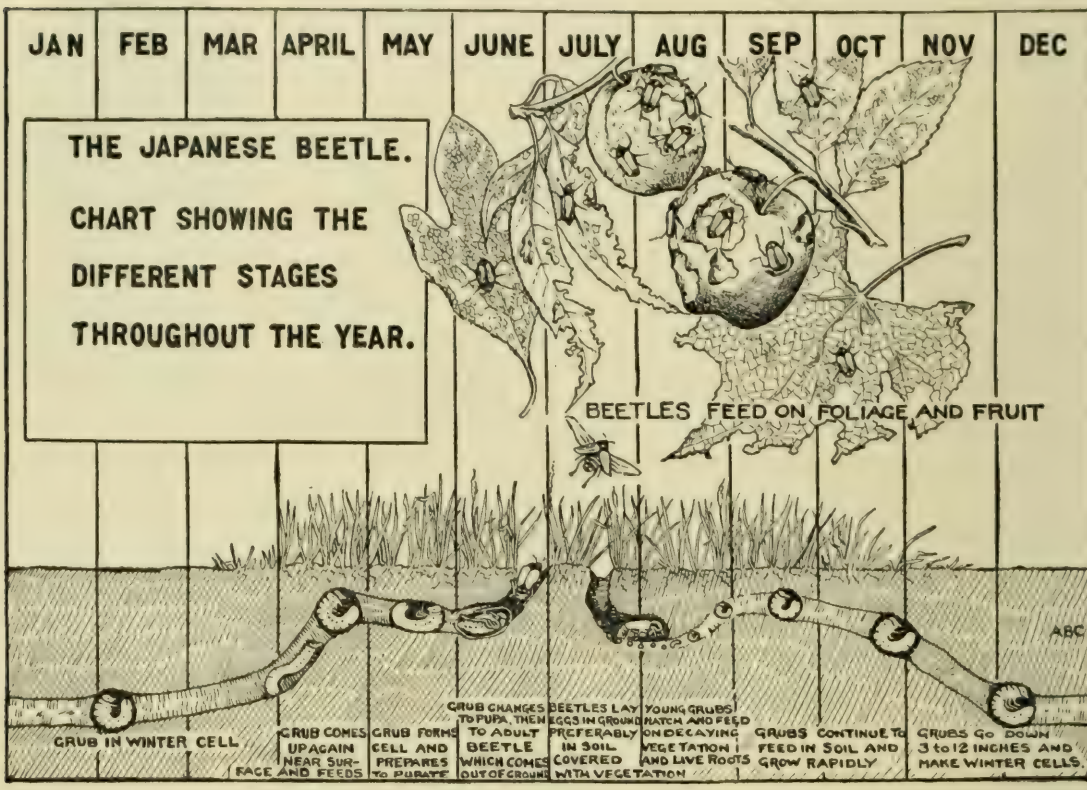


FIG. 404.—Diagram of the life cycle of the Japanese beetle, *Popillia japonica* Newman. (*From Penn. Dept. Agr. Bull.* 390.)

on decaying vegetation, but to some extent on the living roots of grasses and other plants. They frequently cause serious damage to lawns and golf greens. The grub resembles the common white grub, but is smaller, and has some structural differences on the body. There is one generation of the insect each year. The nature of the life cycle is shown by Fig. 404.

Control Measures.—Spraying with arsenicals as recommended for the codling moth will, to a large measure, protect fruit from injury by these insects, not by poisoning the beetles, but by preventing their feeding on the fruit, as they are strongly repelled by such sprays.

An emulsion of oleoresin of pyrethrum flowers and sodium oleate has been found very effective as a contact spray against the beetle. Oil

of geranium is very attractive to the beetles and they may be killed by the above contact spray when concentrated on plants sprayed with this chemical. The larvæ may be killed by drenching the sod of lawns and golf courses with carbon bisulfide emulsion.

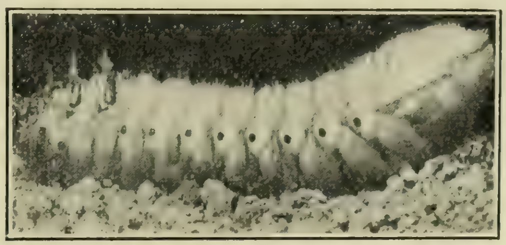
References.—*N. J. Dept. Agr. Bur. Statistics and Inspection, Circ.* 30, 1920 and 46, 1922; *Pa. Dept. Agr. Bull.* 390 (Vol. 7, No. 11), June, 1924; *U. S. Dept. Agr. Dept. Bull.* 1154, 1923; *Jour. Econ. Entomol.*, Vol. 19, pp. 786–790, 1926.

Green June Beetle[1]

Importance and Type of Injury.—Large, somewhat flattened, green beetles, with the margins of the body bronze to yellow, nearly 1 inch long and half as broad (Fig. 405), feed on the foliage of the peach and also on the fruit just before ripening. Thick-bodied, dirty-white grubs, always crawling on their backs (Fig. 405), feed on grass roots and decaying vegetation in the soil.

Plants Attacked.—The adult beetles feed on the foliage of a number of different trees and plants; also occasionally attacking ears of corn and fruits and vegetables of the garden. The larvæ also do considerable injury to the roots of grasses in lawns and golf courses and to a number of vegetables and ornamental plants and in the tobacco seed beds.

a



b

FIG. 405.—Left, adult of green June beetle, *Cotinus nitida* (Linné). Right, full grown larva of green June beetle in natural position when crawling on its back. Twice natural size. (*From U. S. D. A. Dept. Bull.* 891.)

Distribution.—This insect is confined to the southern United States. extending north into Long Island and southern Illinois.

Life History, Appearance, and Habits.—The winter is passed as a grub deep in the soil. In the spring, the grubs burrow close to the surface and feed mainly on decaying vegetable matter. After a heavy rain, they occasionally come out of the soil and crawl on the surface of the ground. When so crawling, they generally lie on their backs and work themselves forward by a peculiar movement of the body ridges. The grubs become full-grown by midspring, change in an earthen cell in the ground to the

[1] *Cotinis nitida* (Linné), Order Coleoptera, Family Scarabæidæ.

pupal stage, and emerge as beetles and feed on the foliage of trees during July and August. Their eggs are laid in soil rich with decaying vegetable matter, on which the grubs feed until cold weather. There is one generation each year.

Control Measures.—There is no satisfactory control for this insect. It does not feed on peach fruits until just about the time for picking, so it is not possible to apply an arsenical spray. About the only thing that can be done is to jar the trees when the beetles are feeding, or hand pick them from the fruit. Manure piles in the vicinity of orchards may act as breeding places for the beetles and so increase their numbers in the orchards. "V"-shaped troughs or flower pots sunk in the ground have proved very effective in trapping the larvæ. In tobacco seed beds they have been controlled by spreading poison-bran bait (see p. 238), at the rate of 1 pound to each 10 square yards.

FIG. 406.—Adult of the oriental fruit moth, *Laspeyresia molesta* Busck; resting on leaf. Four times natural size. (*From Purdue Agr. Exp. Sta. Circ.* 122.)

References.—*N. C. Agr. Exp. Sta. Bull.* 242, 1921; *U. S. Dept. Agr. Dept. Bull.* 891, 1922.

ORIENTAL FRUIT MOTH[1]

Importance and Type of Injury.—The earliest indication of injury by this insect is similar to that of the peach twig borer and consists of a dying back of the new growth of twigs in the spring (Fig. 407). The worms found burrowing in the twigs, however, are not brown like the peach twig borer, but pinkish or creamy-white, with brown heads. The fruit shows injury similar to that of the codling moth. A pinkish-white, short-legged larva, ½ inch long, with a comb-shaped plate on the last segment of the body, may be found inside the fruit (Fig. 408). In many cases, the fruit will not show any blemish through the skin, the young worms having entered through the stem. The fruit may look perfect at the time of picking, but breaks down shortly after packing and shows numerous feeding burrows of the larvæ.

Trees Attacked.—Peach, quince, apple, pear, apricot, plum, and several other fruits.

Distribution.—The oriental fruit moth is an imported insect, having been brought in from the orient previous to 1915. It is now well established over the eastern United States in areas where peaches are grown.

Life History, Appearance, and Habits.—The winter is passed in the form of a full-grown larva about ½ inch in length, closely resembling the codling moth. The larvæ enclose themselves in silken cocoons which

[1] *Laspeyresia molesta* Busck, Order Lepidoptera, Family Olethreutidæ.

they spin on the bark of the trunk or in many cases in rubbish on the ground around the peach orchard. In the spring, the insect changes to the pupal, and then to the moth, stage. The moths (Fig. 406) are gray, with chocolate-brown markings on the wings, and quite closely resemble the codling moth, but are somewhat smaller in size, being about 1/4 inch long. The females lay their eggs on the leaves, and, in some cases, on the twigs. The first-generation worms, upon hatching, bore in the tender

Fig. 407.—Typical injury to peach twigs by larvæ of the oriental fruit moth. *Left*, early summer injury, *right*, a type of injury, consisting of a mass of gum, leaves, and frass, found in fall and winter. (*From Purdue Agr. Exp. Sta. Circ.* 122.)

twigs, and upon becoming full-grown spin cocoons in which they transform to moths. There are from one to seven generations of the insect each year. The later generations attack the fruit in much the same manner as the codling moth attacks the apple, except for the fact that the larvæ do practically no external feeding upon the leaves, and in working their way through the skin of the peach apparently swallow little or none of the particles which they bite off. As already mentioned, many of the larvæ enter the fruit through the stems. These feeding habits prevent the effective use of poison sprays for the control of this insect.

Control Measures.—Up to the present time, no really effective control measure has been found. Early-maturing varieties are less seriously

damaged, and may escape serious injury even where the insect is abundant.

The application of paradichlorobenzene, as used for the control of the peach tree borer (see p. 598) will kill the overwintering larvæ near the base of the trunk. Cultivating the soil of infested orchards, 1 to 3

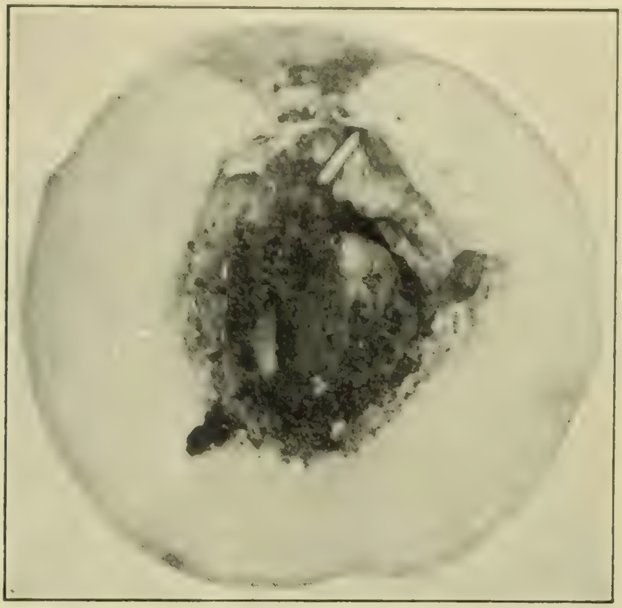


Fig. 408.—Peach injured by oriental fruit moth, showing larva and result of its feeding. About natural size. (*From Purdue Agr. Exp. Sta. Circ.* 122.)

weeks before blooming time, will kill many of the overwintering larvæ in the soil.

References.—*Va. Agr. Exp. Sta. Tech. Bull.* 21, 1921; *Pa. Dept. Agr. Bull.*, Vol. 8, No. 9, June, 1925; *Purdue Agr. Exp. Sta. Circ.* 122, 1925. *Ohio Agr. Exp. Sta. Bimonthly Bull. Mch.-Apr.*, 1928.

Green Peach Aphid[1]

Importance and Type of Injury.—Greenish aphids or plant lice, sucking the sap from the new fruits and twigs of peach and a number of other trees and herbaceous plants.

Plants Attacked.—The food plants of this insect include peach, plum, apricot, cherry, many ornamental shrubs, and garden and flowering plants (see also page 512).

Distribution.—This insect is a native of Europe but is now generally distributed over North America.

Life History, Appearance, and Habits.—The winter is passed in the form of black shining eggs on the bark of the peach, plum, apricot, and cherry. The young aphids, which are pale yellowish-green in color, with three dark lines on the back of the abdomen, begin to hatch about the time the peach blooms. On becoming full-grown, they begin giving birth to living young, generally remaining on the peach for two or three generations, after which most of the individuals acquire wings and migrate to garden plants in late spring. On the approach of cold weather in the fall, the females fly to the peach, where they give birth to the true sexual females. These mate

[1] *Myzus persicæ* (Sulzer), Order Homoptera, Family Aphididæ.

with males that fly over from the summer host plants and the fertilized females deposit their eggs in the above mentioned situations.

Control Measures.—The control measures for this aphid are the same as for other aphids; that is, spraying or dusting with a strong contact insecticide. A 40 per cent nicotine-sulfate solution, used at ½ pint to 50 gallons of water, with 1 pound of potash fish-oil soap dissolved in each 25 gallons of water, will kill all aphids hit by it. A 3 per cent nicotine dust also is effective.

References.—*Pa. Agr. Exp. Sta. Bulls.* 185 and 186, 1924; *Colo. Agr. Exp. Sta. Bull.* 133, 1908; *N. J. Agr. Exp. Sta. Circ.* 107, p. 5, 1919.

Tarnished Plant Bug[1]

Importancé and Type of Injury.—This insect, which feeds on many different kinds of plants, is particularly injurious to the peach. In the nursery rows, peach trees will be found with the main terminal and a

Fig. 409.—Tips of peach nursery trees injured by the feeding of the tarnished plant bug. (*From Slingerland and Crosby, "Manual of Fruit Insects," copyright* 1915, *by the Macmillan Company. Reprinted by permission.*)

number of laterals wilting and dying back (Fig. 409), but not containing borers. Young trees thus injured become scrubby or brushy. The insect also causes sunken areas on the sides of the fruit which are free from down, looking as though the peach had been gouged or partly peeled, when small. This injury is commonly called "cat-facing" (Fig. 410).

Plants Attacked.—Many kinds of trees and herbaceous plants; a very general feeder.

Distribution.—Throughout the world.

Life History, Appearance and Habits.—The tarnished plant bug passes the winter as a full-grown insect. It is of a coppery-brown color, flecked

[1] *Lygus pratensis* Linné, Order Hemiptera, Family Miridæ.

with darker brown and yellow. The body is oval in shape, somewhat triangular in front, about $\frac{1}{4}$ inch long, and about half as wide (Fig. 292). The insect hibernates in many different kinds of shelter, but seems to prefer plants which do not entirely die down. Large numbers of them have been found in winter between the leaves of mullen, wild parsnip, alfalfa, and clover. The insects become active during the first warm days of spring. They fly to trees, feed by sucking the sap, and while feeding apparently inject some substance that is highly injurious to the plant tissue. The feeding causes the peach to die back, resulting in a condition usually referred to by nurserymen as "stopback" (Fig. 409). There are several generations of the insect each season, the eggs being laid mainly in the stems of herbaceous plants, including some cultivated plants and weeds. A few eggs are laid in the peach terminals and also occasionally in the peach fruits (see also p. 445).

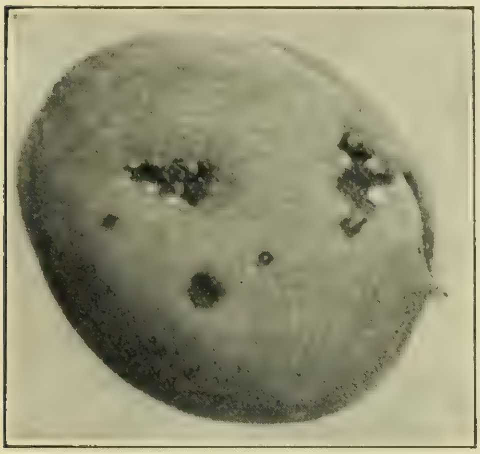


FIG. 410.—Typical "cat-facing" of peach, caused by feeding of the tarnished plant bug. (*From Ill. State Nat. Hist. Sur.*)

Control Measures.—No satisfactory control measures have as yet been found for this insect. Keeping down weeds about the orchard is of some value in reducing its numbers.

References.—*Mo. Agr. Exp. Sta. Research Bull.* 29, 1918; *N. Y. (Cornell) Agr. Exp. Sta. Bull.* 346, 1914; *Ill. State Nat. Hist. Survey, Bull.* Vol. 17, Art. VI, 1928.

E. PLUM INSECTS

The insects that attack the plum are very much the same as those that attack the peach; in fact, there are only one or two insects of special importance on the plum.

FIELD KEY FOR THE IDENTIFICATION OF INSECTS INJURING THE PLUM

1. Partly grown plums are "stung" and drop from the tree (see *C*, 1 under key for insects that attack the fruit of the peach). *Plum curculio,* page 613.

2. Plums of the Japanese and European varieties have the branches coated with grayish scales, having much the color of wet ashes. Mature trees of the Americana varieties are seldom injured (see *B*, 1 under key for insects injuring the peach). *San José scale,* page 613.

3. Tips of new growth on plum trees literally covered with brownish, blackish, or light-green aphids. Leaves badly curled, growth stunted, fruit sometimes misshapen and shriveled. *Rusty plum aphid or hop aphid,* page 613.

4. About the time the plum trees come into full foliage, silken webs are found enclosing the leaves at the ends of branches. Feeding on the leaves within the webs are smooth-bodied, grayish-yellow, many-legged caterpillars, up to $\frac{3}{4}$ inch long.

Black wasp-like insects deposit eggs on the midribs of the plum leaves just previous to the appearance of the webs. *Web-spinning sawfly, Neurotoma inconspicua* (Norton) (see *South Dakota Agr. Exp. Sta. Bull.* 190, 1920).

5. Leaves of plum and other fruits show a pale sickly appearance as though covered with dust or brownish-red specks. Very light webs over the surface of the leaves, upon which are crawling minute, reddish, eight-legged mites. *European red mite*, page 554.

Plum Curculio[1]

The plum curculio has already been discussed under both apple and peach (see pp. 577 and 604). It is perhaps more destructive to plums than to any other fruit. The curculio is one of the main agencies in spreading brown rot. If this very destructive disease of the fruit is to be controlled, it is necessary to control the plum curculio.

Control Measures.—The methods of control which are given for this insect on the peach will apply equally well for the plum. Particular attention should be given to clean cultivation of the plum orchard and to picking up the early-dropped plums. In spraying for this insect on plums the first application should be made just before the blossom buds open, using arsenate of lead at the rate of 1½ pounds to 50 gallons of spray mixture. The second spray should be given as soon as the shucks have fallen from the plums, using the same amount of lead as in the previous spray. A third spray should be given 10 days to 2 weeks after the second. One additional spray 2 or 3 weeks later is sometimes necessary in years when the curculio is abundant.

San José Scale[2]

This scale is very destructive to plums belonging to the Japanese or European varieties; that is, such varieties as Lombard, Green Gage, Fallenberg, Burbank, and many others. The scale is not, however, of great importance on mature American plum trees, such as the wild goose or other varieties of *Americanas.* The San José scale may cause injury to young plum trees of any variety (see p. 539).

Plum Aphids

There are several species of aphids which attack the plum. They often appear in very large numbers on the tips of the plum twigs (Fig. 411) and by their feeding curl the leaves, stunt the growth, and injure the tree and fruit by the discharge of honeydew. The hop aphid[3] and the rusty plum aphid[4] are common species.

[1] *Conotrachelus nenuphar* (Herbst), Order Coleoptera, Family Curculionidæ.

[2] *Aspidiotus perniciosus* Comstock, Order Homoptera, Family Coccidæ.

[3] *Phorodon humuli* (Schrank), Order Homoptera, Family Aphididæ.

[4] *Hysteroneura setariæ* (Thomas), Order Homoptera, Family Aphididæ.

Control Measures.—While several species of aphids are involved, the control measures are essentially the same. As soon as the aphids appear, the trees should be thoroughly sprayed with nicotine sulfate, used at the rate of ½ pint to 50 gallons of water or spray mixture. If water is used alone, add 2 pounds of potash fish-oil soap to each 50 gallons of the solution. During the last few years a more satisfactory control has been

FIG. 411.—Rusty plum aphids, *Hysteroneura setariæ* (Thomas), clustered on plum. About natural size. (*From U. S. D. A. Farmers' Bull.* 908.)

obtained by dusting with 2½ per cent nicotine dust. Such a dust may be made by mixing hydrated lime and nicotine sulfate (see p. 241).

References.—*Pa. Agr. Exp. Sta. Bull.* 182, 1923; *U. S. Dept. Agr. Dept. Bull.* 774, 1913; *Okla. Agr. Exp. Sta. Bull.* 88, 1910.

F. CHERRY INSECTS

The cherry, like the plum, is attacked by many of the insects which affect the peach. Sour cherries are not subject to severe injury by San José scale, but it is a serious pest of sweet cherries. Cherries are sometimes attacked by the peach tree borer, lesser peach tree borer, and bark beetles; and the same control measures may be used as on peach. Some of the aphids that attack the plum attack also the cherry, and there are several other species which confine their work largely to this tree. The methods of control are the same as for these insects on plum.

The sweet cherry is attacked by practically the same insects as those feeding on the sour cherry and is also very subject to injury by the San José scale. Wherever sweet cherries are grown, especially while the trees are young, they should receive a dormant treatment for San José scale, the same as that given the apple or peach.

FIELD KEY FOR THE IDENTIFICATION OF INSECTS INJURING THE CHERRY

1. Cherries are "stung" but seldom drop. White, footless grubs up to ⅓ inch long feed inside the fruit (see *C*, 1, under key to insects that attack the fruit of the peach). *Plum curculio*, page 577.

2. Cherries misshapen, undersized, ripening prematurely, or the fruit partly decayed or shrunken and wrinkled on one side. Yellowish-white maggots up to 1/4 inch long burrow in the injured fruit. Black flies, smaller than a house fly, with the abdomen marked with white crossbands and the thorax margined with yellow, and with four black bands on the wings, are found resting on the foliage or on the fruit. *Cherry fruit flies*, page 615.

3. Fawn-colored, very long-legged, slender-bodied beetles, about 1/2 inch long, attack ripening fruits often in swarms. Most abundant in sandy areas and disappear within a month. *Rose chafer*, page 625.

4. Soft, fleshy, dark-green to orange, slimy, slug-like larvæ, up to 1/2 inch in length, feed on the surface of cherry leaves and skeletonize the leaf. Most abundant during late spring and again in late summer. In the late spring, black-and-yellow wasp-like insects, about 1/5 inch long, lay their eggs on the leaves of cherry. *Pear* or *cherry slug*, page 616.

5. Grayish, very thin, flaky scales, up to 1/8 inch across, and with a raised, reddish, nipple-like area in the center of the scale are found clustered or massed on the bark of cherry. The scales covering the reddish-yellow bodies of the insects are thinner and more translucent than those of the San José scale. *Forbes' scale*, page 617.

6. Grayish scales on the bark of sweet cherry, and rarely on sour cherry (see *B*, 1, under key for insects injuring the peach). *San José scale*, page 539.

Plum Curculio

Most of the wormy cherries in many parts of the country are caused by the plum curculio. This insect is especially abundant on cherry trees grown in small orchards or in cities. The control measures for this insect are the same as those given for its control on the plum (see page 613).

Cherry-fruit Flies[1,2]

Importance and Type of Injury.—There are two closely related flies which attack the cherry and cause wormy fruits. Cherries are somewhat misshapen and undersized, turning red ahead of the main crop, oftentimes with one side of the fruit partly decayed and shrunken or wrinkled and closely attached to the pit. Yellowish-white, footless maggots, 1/4 inch long and pointed at the head end, will be found in the flesh of the fruit (Fig. 412). Brown burrows extend through the fruit.

Trees Attacked.—Cherry, pear, plum.

Distribution.—Northern United States and Canada.

Life History, Appearance, and Habits.—The winter is passed in brown, capsule-like cases (puparia) in the soil. The adult flies begin to emerge during late spring, and fly to cherry trees, where the females lay their eggs in the flesh of the nearly ripe fruit. These flies (Fig. 413) are a little smaller than a house fly, of a general black color, marked with yellow margins on the thorax. The true cherry-fruit fly[1] has white crossbands on the abdomen, which are not found on the black-bodied cherry-fruit fly.[2] There are blackish bands on the wings. The maggots

[1] *Rhagoletis cingulata* Loew. Order Diptera, Family Trypetidæ.

[2] *Rhagoletis fausta* Osten Sacken.

on hatching from the eggs feed in the flesh of the fruit, causing decay and the injuries already described. On becoming full-grown, they drop to the ground and work their way below the surface, where they change into the pupal stage in which they pass the winter.

Control Measures.—The spray schedule used for the control of the plum curculio will give a very satisfactory control of these insects. In this schedule, the first summer spray consists of 1 gallon of commercial lime-sulfur and 1½ pounds of arsenate of lead to 50 gallons of water. This should be applied just after the blossom-buds open. A second spray, using the same ingredients, should be given as soon as the shucks have fallen from the young cherries. A third spray of the same materials should be given 10 days later. These sprays protect the fruit by poisoning the adult flies.

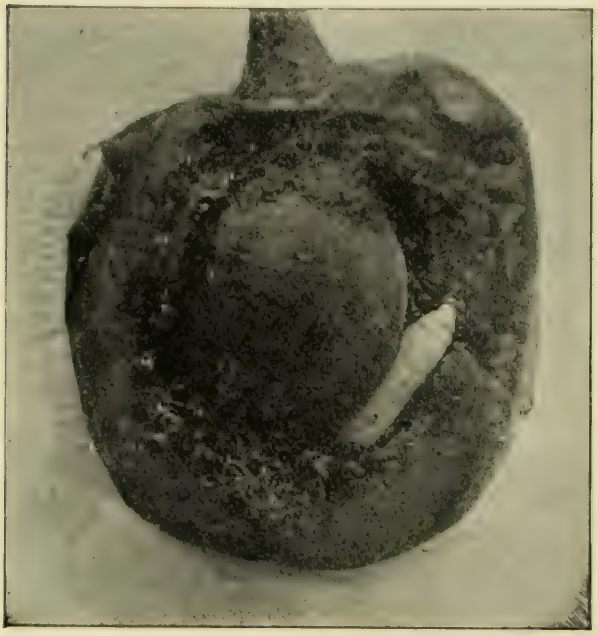


FIG. 412.—Section of ripe cherry showing maggot of the cherry fruit fly at work. About three times natural size. (*From N. Y. (Cornell) Agr. Exp. Sta. Bull.* 325.)

FIG. 413.—Adult of the cherry fruit fly, *Rhagoletis cingulata* Loew, about four times natural size. (*From N. Y. (Cornell) Agr. Exp. Sta. Bull.* 325.)

References.—*N. Y.* (*Cornell*) *Agr. Exp. Sta. Bull.* 325, 1912; *Ont. Dept. Agr. Bull.* 227, 1915.

PEAR SLUG[1]

Importance and Type of Injury.—Small, fleshy, dark-green to orange slug-like, slime-covered larvæ, up to ½ inch in length, with the front part of the body enlarged, feed on the surface of the cherry leaves and skeletonize the leaves, leaving only a framework of veins (Figs. 146, 414).

Trees Attacked.—Cherry, pear, plum.

Distribution.—Throughout the United States.

Life History, Appearance, and Habits.—This insect, like many other sawflies, passes the winter in a cocoon formed in an earthen cell 2 or 3

[1] *Eriocampoides limacina* Retzius, Order Hymenoptera, Family Tenthredinidæ.

inches below the surface of the ground. In the late spring, shortly after the cherries have come into full leaf, black-and-yellow sawflies, $\frac{1}{5}$ inch long, emerge from these cocoons. The insects are a little larger than the common house fly. They have four wings. The female sawfly inserts her eggs in the leaves, and after a few days these eggs hatch into the soft-bodied worms or slugs which feed on the leaf as above described. The feeding period varies from 2 to 3 weeks. As the slugs grow in size, they become somewhat lighter in color, until when full-grown they are nearly orange-yellow. They then crawl or drop to the ground, into which they burrow, and there change to the pupal stage. Adults emerge during late July and August and lay eggs for the second generation of slugs. It is this generation that usually causes

Fig. 414.—Larvæ of the pear slug, *Eriocampoides limacina* Retzius, and characteristic injury on leaf. About twice natural size. (*From Slingerland and Crosby, "Manual of Fruit Insects," copyright* 1915, *by the Macmillan Company. Reprinted by permission.*)

the greatest amount of injury, especially on young trees, which they may completely defoliate. When this second generation becomes full-grown, they go into the ground and remain there during the winter.

Control Measures.—The pear slug is very easily poisoned. An application of arsenate of lead, at the rate of 1 pound to 50 gallons of water applied as soon as the young slugs are noticed on the leaves, will give complete control. Dusting the trees with arsenate of lead, 1 pound, mixed with 5 pounds of hydrated lime is also effective. The spray schedule already given for the control of the curculio, and fruit flies, is effective in controlling the slug.

References.—*State Entomol. So. Dak. Circ.* 27, 1918; *Iowa Agr. Exp. Sta. Bull.* 130, 1912.

Forbes' Scale[1]

Importance and Type of Injury.—As already stated, the San José scale is of little or no importance on sour cherries. The Forbes' scale, which resembles the San

[1] *Aspidiotus forbesi* Johnson, Order Homoptera, Family Coccidæ.

José scale in general appearance, is often very abundant, although not seriously destructive to the tree. Grayish, thin, flaky scales are massed on the bark of the trunk and branches of the tree, sometimes completely covering the bark (Fig. 415). Examination with a microscope will show a raised reddish area in the center of each scale which will distinguish it from the San José scale.

Plants Attacked.—Cherry, apple, apricot, pear, plum, quince, and currant.

Distribution.—Throughout the United States east of the Rocky Mountains.

Life History, Appearance, and Habits.—The winter is passed as a partly grown scale, somewhat resembling the San José scale, but the raised area in the center of

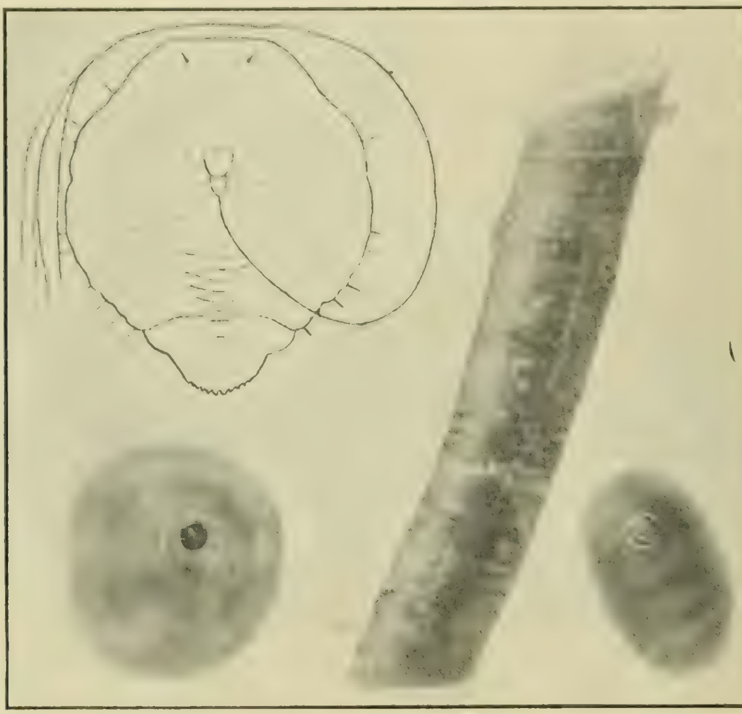


FIG. 415.—Forbes' scale, *Aspidiotus forbesi* Johnson. Mature female removed from scale, upper left, greatly enlarged; female scale, lower left, much enlarged; male scale, lower right, much enlarged; infested twig, somewhat reduced. (*From Ill. State Nat. Hist. Sur.*)

the scale has a reddish or orange color. In Illinois, the first young appear in May, and are produced both from eggs and by the birth of nymphs. There are from one to three generations each season.

Control Measures.—The control given for the San José scale (see p. 542), by the application of lime-sulfur at the recommended dormant strengths, is very effective in the control of this scale.

Reference.—Twenty-second Rept. Ill. State Entomol., p. 115, 1902.

G. APRICOT INSECTS

The apricot is injured by practically the same insects as the plum, and the same control measures will apply on this tree. Plum curculio is often very destructive to apricot, and where this fruit is grown special attention should be given to this insect. San José scale is also often very serious, especially on the younger trees.

II. GRAPE INSECTS

FIELD KEY FOR THE IDENTIFICATION OF INSECTS INJURING THE GRAPE

A. Chewing insects attacking the leaves, fruits, or roots:

1. Greenish-gray to purplish caterpillars up to ½ inch in length, with brown heads, feed on or in the grape berries, under protecting webs, and often attach bits of leaves to the berries. *Grape-berry moth,* page 619.

2. Vines show a lack of vigor, the foliage yellowing, and little growth being made. Small, chain-like holes are eaten in the leaves by brown to grayish beetles about ⅓ inch long; especially abundant about 2 weeks after grapes bloom. White grubs about ½ inch long, with brown heads, eat off the small, fibrous roots and score the bark of the larger roots during the late summer. *Grape rootworm,* page 622.

3. Small, active, jumping beetles of a metallic, greenish-blue color, feed on the unfolding leaves of grape in the spring. Light-brown, black-spotted grubs, the largest about ⅓ inch in length, feed in company with the beetles and, later, on the opened leaves. *Grape flea beetle,* page 624.

4. Fawn-colored, long-legged, slender-bodied beetles, about ½ inch long, feed on the blossoms, newly set grapes and leaves. Most abundant in sandy areas and during the first 2 weeks after blooming. *Rose chafer,* page 625.

B. Sap-sucking insects attacking leaves or roots:

1. Vines lacking in vigor, sickly in appearance, the foliage pale, with many tiny whitish spots over the leaves. Very slender, yellowish bugs, with red marks on the wings, about ⅛ inch long by a fourth as wide, and their active light-colored nymphs, suck the sap from the underside of leaves. The nymphs run sidewise as readily as forward. *Grape leafhopper,* page 627.

2. Vines lack vigor, often dying. Rounded, irregular galls, about half the size of a pea, on the leaves, sometimes covering them. The galls open on the underside of the leaves and the inside is lined with many, small, wingless, pale-yellow aphids. Knots or galls on the roots are covered with aphids similar to those on the leaves, causing the roots to rot off. *Grape phylloxera,* page 629.

Grape-berry Moth[1]

Importance and Type of Injury.—This insect is almost universally present wherever grapes are grown, either as a few vines in a back yard or in extensive vineyards. The grape berries are webbed together, turning dark purple in color, and drop from the stems when the grapes are about the size of garden peas. Small holes are eaten in the nearly ripened grapes, the sides of which are attached by a light web to a bit of leaf, or to adjoining berries. Small silken cocoons lie in small, semicircular flaps cut in the grape leaves, folded over, and held together by a light web. When this insect is abundant, it will often destroy as much as 60 to 90 per cent of the fruit in unsprayed vineyards.

Plants Attacked.—Grape.

Distribution.—Throughout the northern United States and southern Canada.

Life History, Appearance, and Habits.—This insect passes the winter in grayish silken cocoons, nearly always folded in fallen grape leaves.

[1] *Polychrosis viteana* Clemens, Order Lepidoptera, Family Olethreutidae.

Occasionally the cocoons may be attached to the loose scales of bark or in rubbish on the ground. In the late spring, shortly after the grape has bloomed, a grayish or grayish-purple moth, about ½ inch across the

FIG. 416.—Grape-berry moth, *Polychrosis viteana* Clemens. Adult, natural size and enlarged. (*From N. Y. (Cornell) Agr. Exp. Sta. Bull.* 223.)

wings (Fig. 416), emerges from the cocoon, and the female lays her eggs on the newly forming grape berries. The little worms hatching from these eggs spin a silken web wherever they go and thus web together the

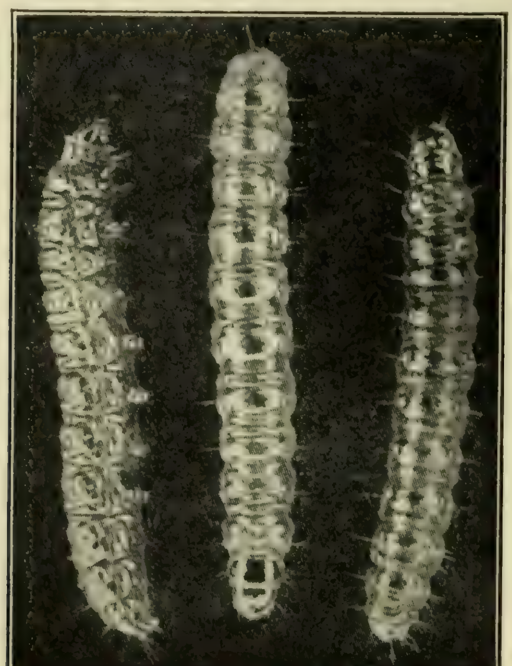


FIG. 417.—Grape-berry moth. Larvæ or caterpillars, about four times natural size. (*From N. Y. (Cornell) Agr. Exp. Sta. Bull.* 223.)

fruit clusters, or parts of clusters (Fig. 418). They feed on the grape berries and each worm of this generation will usually destroy a number of grapes. On becoming full-grown, the worms are about ½ inch long,

greenish-gray with brown heads (Fig. 417). Each cuts out and folds over a little flap of leaf, and within this spins a cocoon. The moths of the second generation emerge during July, and deposit their eggs on the grape berries like those of the first generation. While a single worm may find sufficient food in one berry to complete its development, it often goes from one grape to another, especially where the berries are touching, and thus may destroy three or four grapes before it completes its growth. When full-grown, they again go to the leaves where they spin their cocoons, pupate, and remain in this stage during the winter.

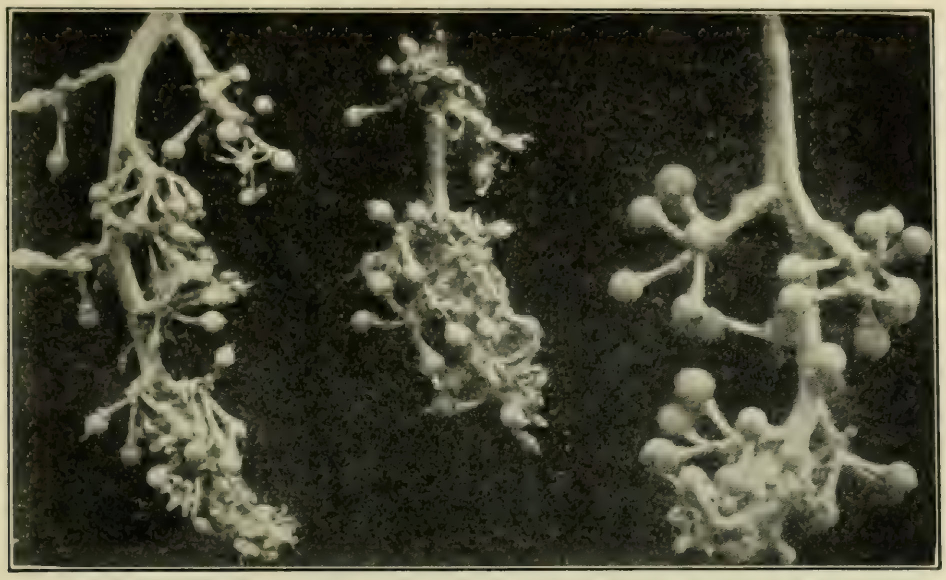


Fig. 418.—Work of spring generation of grape-berry moth larvæ among blossoms and young fruits in June. Natural size. (*From N. Y. (Cornell) Agr. Exp. Sta. Bull.* 223.)

Control Measures.—Spraying is the most effective control for this insect. Extensive experiments in the large grape belt of Ohio and New York, have shown that thorough spraying with arsenate of lead, at the rate of 3 pounds to 50 gallons of Bordeaux mixture, will give almost complete control of this insect. Three sprays should be applied: one shortly after the fruit has set, the second about 10 days later, and a third when the grapes are approximately half grown. On account of objectionable arsenical residue on the marketed fruits the third spray should contain only 1 pound of arsenate of lead with 1 pound rosin fish-oil soap to each 50 gallons of spray. To cover the berries of the grape thoroughly, it is necessary to use a high-pressure sprayer that will break the spray into very fine particles. In addition to the spraying, a partial control of the insect may be accomplished by thoroughly cleaning up around the grape vineyards and raking up and burning the fallen leaves during the fall or winter.

References.—*Jour. Econ. Entomol.*, Vol. 14, p. 488, 1921; *Ohio Agr. Exp. Sta. Circ.* 63, 1906; *U. S. Dept. Agr. Dept. Bull.* 550, 1917.

Grape Rootworm[1]

Importance and Type of Injury.—Vines show a lack of vigor, the leaves turn yellow, and little new growth is made. An examination of the roots will sometimes show small whitish grubs eating off the small feeding roots, and gouging out numerous channels in the bark of the larger roots. Grayish-tan beetles feed upon the leaves. Not the entire leaf is eaten, but series of small holes are made through the leaf in chain-like rows (Fig. 420).

Plants Attacked.—Grape.

Distribution.—Eastern United States, except extreme north and south.

Life History, Appearance, and Habits.—The grape rootworm passes the winter in the form of a small white grub about ½ inch long. The

Fig. 419.—Adult of the grape rootworm, *Fidia viticida* Walsh, on leaf, about three times natural size. (*From N. Y. (Geneva) Agr. Exp. Sta. Bull.* 453.)

head is brown and the insect holds its body in a curved position. During the winter these worms make their way deep into the soil and will be found 2 feet or more below the surface of the ground. As the soil warms in the spring, the grubs migrate back to within 1 or 2 inches of the surface and excavate small cells, in which they change to very soft white pupæ. About 2 weeks after the grapes bloom, they emerge from these cells as small brown or grayish beetles. These beetles are about ¼ inch long, and are rather chunky in appearance (Fig. 419). They feed on the upper surface of the grape leaf, producing the effect on the foliage above described. Shortly after commencing to feed, the females deposit their eggs, in masses averaging about 100 eggs each. The eggs are attached to the grape canes, usually under the loose bark scales, although sometimes not so protected. The beetles do not all come out at once, and the period

[1] *Fidia viticida* Walsh, Order Coleoptera, Family Chrysomelidæ.

of their feeding and egg-laying may extend over a month or 6 weeks. The eggs hatch after a short time, and the young grubs drop to the ground, where they burrow into the soil until they encounter grape roots. They at once start feeding on these roots, cutting off the slender feeding roots, and channeling or gouging the bark of the larger roots. On the approach of cold weather, they work their way deeper into the soil, where they remain during the winter. There is one generation each year.

FIG. 420.—Typical injury of adult grape rootworms on leaves. About natural size. (*From N. Y. (Geneva) Agr. Exp. Sta. Bull.* 453.)

Control Measures.—As the beetles of the grape rootworm feed extensively on the upper surface of the leaves, they may be poisoned by arsenate of lead, applied at the rate of 3 pounds to 50 gallons of water or of Bordeaux mixture. The first spray for this insect should be given as soon as any of the feeding punctures are noticed on the leaves. The time of the appearance of the beetles will be about 2 weeks after the grapes are through blooming. Thorough spraying of all grape foliage is essential in the control of this insect. The beetles are somewhat repelled by the arsenate of lead, and if a part of the foliage is not sprayed, they will be

nearly sure to feed upon it. A second spray should be made 10 days to 2 weeks after the first. The two sprays, if thoroughly applied, are sufficient to control this insect. Bordeaux mixture alone has no marked repellent effect on this beetle, and vineyards that were sprayed with Bordeaux, without the addition of the arsenate of lead, have in a number of cases been very seriously damaged by the grape rootworm.

References.—*U. S. Dept. Agr. Bur. Entomol. Bull.* 68, Part VI, 1908; *N. Y.* (*Geneva*) *Agr. Exp. Sta. Bull.* 453, 1918; *N. Y.* (*Geneva*) *Agr. Exp. Sta. Bull.* 519, 1924.

Fig. 421.—Grape flea beetle, *Haltica chalybea* Illiger, natural size and enlarged. (*From N. Y.* (*Cornell*) *Agr. Exp. Sta. Bull.* 157.)

Grape Flea Beetle[1]

Importance and Type of Injury.—Small jumping beetles, about ⅕ inch long, having a dark, metallic, greenish-blue color (Fig. 421), feed on the buds of the grape just as they are starting to unfold in the spring. The buds are eaten off, and the newly opening foliage presents a ragged, tattered appearance. Light-brown, black-spotted grubs about ⅓ inch long will be found feeding on the newly opening leaves, along with the beetles.

[1] *Haltica chalybea* Illiger, Order Coleoptera, Family Chrysomelidæ.

Plants Attacked.—Grape, plum, apple, quince, beech, elm, and Virginia creeper.

Distribution.—Eastern two-thirds of the United States.

Life History, Appearance, and Habits.—The adult grape flea beetles pass the winter in hibernation in or near the grape vineyards, under any shelter which they can find. They become active fairly early in the spring, and at once start feeding on the opening grape leaves. The females soon start laying their eggs, which are deposited in masses underneath the loose bark of canes, or occasionally on the upper surface of the leaves. The eggs are light yellow in appearance and are fairly conspicuous. Small dark-brown to blackish grubs hatch from these eggs and feed on the surface of the leaves and on the clusters of the blossom buds. On becoming full-grown, the larvæ, which are then lighter brown, with regular rows of blackish spots (Fig. 422), drop or crawl to the ground, enter the soil, and there change to the beetle stage. The adult beetles

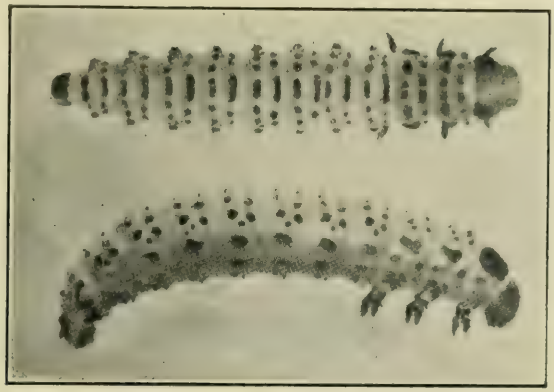


Fig. 422.—Larvæ of the grape flea beetle, dorsal and lateral views. About four times natural size. (*From N. Y. (Cornell) Agr. Exp. Sta. Bull.* 157.)

of the summer generation make their appearance during July and August, and feed on the grape leaves until the approach of cold weather. They rarely cause much injury during this part of the season.

Control Measures.—A strong arsenate of lead spray, applied as soon as the beetles make their appearance on the vines in the spring, is somewhat effective as a control measure, but because of the limited amount of foliage which can be covered with poison at this time, it is often hard to protect the vines from injury by this insect. When the grubs are present on the leaves, using arsenate of lead at the rate of 2 pounds to 50 gallons of water, or Bordeaux mixture, is effective in killing the grubs. On a few backyard vines, the insect may be controlled by spreading a piece of cloth, dipped in oil, under the vines and jarring the beetles on to it. Fall clean-up of the vineyards, as recommended for the control of the grape-berry moth, will also help in keeping down the numbers of this insect.

References.—*U. S. Dept. Agr. Dept. Bull.* 901, 1920; *Me. Agr. Exp. Sta. Bull.* 273, 1918; *N. Y. (Geneva) Agr. Exp. Sta. Bull.* 331, 1910.

Rose Chafer[1]

Importance and Type of Injury.—The leaves of grape, and especially the blossoms, are eaten by gray or fawn-colored, long-legged, slender beetles about ½ inch long (Fig. 423, *a*). Newly set grapes are eaten and bunches of grapes nearly ruined. The insects are most abundant on the grape for the first 2 or 3 weeks after bloom, but will be found in smaller

[1] *Macrodactylus subspinosus* Fabricius, Order Coleoptera, Family Scarabæidæ.

numbers for the next week or 10 days. The beetles also eat ripening cherries and riddle the buds and leaves of roses.

Plants Attacked.—Grape, apple, peach, cherry, pear, strawberry, rose, peony, blackberry, raspberry, Virginia creeper, corn, bean, beet, pepper, cabbage, poppy, hollyhock, mullen, clover, small grains and grasses, and a great variety of other plants, trees, and shrubs.

Distribution.—The insect is generally distributed over the eastern United States and southeastern Canada. Its injuries are more severe in sandy areas.

FIG. 423.—The rose chafer, *Macrodactylus subspinosus* Fabricius. *a*, adult; *b*, larva; *c* and *d*, mouth parts; *e*, pupa; *f*, injury to leaves and blossoms of grape with beetles at work. *a*, *b*, *e*, enlarged, the lines show natural size; *c* and *d* more enlarged; *f*, slightly reduced. (*From U. S. D. A. Farmers' Bull.* 721.)

Life History, Appearance, and Habits.—The winter is passed in the larval or grub stage. The larva (Fig. 423, *b*) closely resembles that of the common white grub, but is somewhat more slender, and much smaller. When full-grown, it is about ¾ inch in length. The larvæ are found in uncultivated land, especially in sandy areas, to a depth of 10 to 16 inches. In the spring, the nearly full-grown larvæ work their way toward the surface of the ground and feed for a short time on the roots of grasses, grains, weeds, and other plants. They pupate during May, and remain in this stage (*e*) for about 3 weeks, emerging as adults at about the time when the grapes come into bloom. The adult (*a*, *f*); is a very ungainly

beetle, nearly ½ inch in length, with reddish-brown head and thorax and the under surface of the body blackish in color. The whole body is covered with small yellow hairs, which give the beetle a fawn-colored appearance. They feed chiefly on the surface of the plants, and the females, after mating, deposit their eggs in groups of from 6 to 25, at a depth of about 6 inches in the soil. While the eggs are grouped, each egg is laid in a separate pocket in the soil. The eggs hatch in approximately 2 weeks, and the young larvæ feed on the roots of grasses and other plants for the remainder of the summer, going down in the soil on the approach of cold weather.

Control Measures.—The most important method of controlling this insect is thoroughly to cultivate the areas about the vineyard where the eggs may have been deposited. Very few grubs of the rose chafer have been found in land where cultivated crops, such as potatoes and corn, are being grown. Cultivation is most effective in killing the insects if carried on during May and early June, when the rose chafer is in the pupal stage. A spray consisting of 4 pounds of arsenate of lead and 1 gallon of molasses to 50 gallons of water, applied as soon as the beetles appear, and at intervals of about 1 week if the infestation continues severe, has proved very effective in controlling the beetles in Canada. Arsenate of lead alone is of some value, but the effectiveness of the material is apparently increased by the addition of the molasses. In order to secure the maximum protection from cultivation, it is necessary that all grape growers unite in keeping the areas, surrounding vineyards, under cultivation.

References.—*53rd Rept. Entomol. Soc. Ont.*, p. 60, 1922; *U. S. Dept. Agr. Bur. Entomol. Bull.* 97, Part III, 1911.

Grape Leafhopper[1]

Importance and Type of Injury.—There is no insect which attacks the grape that is so universally present, year in and year out, as the grape leafhopper. Very small, whitish spots appear over the grape leaves (Fig. 2, *B*). The entire leaf becomes a pale greenish-yellow in color, the vines show very little vigor, and the foliage presents a general sickly appearance. Numerous, small, pale, red-flecked, very active insects are found feeding on the undersides of the leaves. These insects never cause any ragging of the foliage.

Plants Attacked.—Grape, Virginia creeper, apple, and many other plants.

Distribution.—Throughout the United States.

Life History, Appearance, and Habits.—The adult grape leafhoppers (Fig. 424, *right*) are of a pale yellowish color with red markings on the wings. They pass the winter among the fallen grape leaves, grasses, or other shelters in the vicinity of the vineyard. The hoppers are about ⅛

[1] *Erythroneura comes* (Say), Order Homoptera, Family Cicadellidæ.

inch or less in length by one-fourth as wide. They become active about the time the grape leaves are half grown, and fly to the leaves, on which they feed by sucking the sap from the underside. After feeding 2 or 3 weeks, the female hoppers begin to lay their eggs. These eggs, which are very small, are pushed into the tissue of the leaf veins. They hatch into pale green or greenish-white nymphs (Fig. 424 *left*), which are wingless, but extremely active, and which feed by sucking the sap, remaining almost entirely on the undersides of the leaves. They become full-grown in from 4 to 5 weeks, depending largely on the temperature of the season. These insects do not go through any pupal stage, merely shedding their skins as they grow and becoming larger each time until the full-grown, adult, winged stage is reached. There are probably two

FIG. 424.—The grape leafhopper, *Erythroneura comes* (Say), about seven times natural size. (*From U. S. D. A. Dept. Bull.* 19.)

generations of the insect in most of its range, with a third generation in the south. The nymphs of the last generation become full-grown during September, and the adults seek the shelters above described about the time of the first frost.

Control Measures.—Because of the fact that these insects are sap feeders, and because of the activity of the adults and nymphs, they are very difficult pests to control. The best methods thus far developed are spraying or dusting with nicotine compounds. Nicotine sulfate should be used at the rate of ½ pint to each 50 gallons of spray mixture. If the nicotine sulfate is used with water alone, 2 pounds of potash fish-oil soap should be dissolved in each 50 gallons of water. If used with Bordeaux mixture the soap is not necessary. For a few vines in yards or gardens, the solution should be made up at the rate of 1 tablespoonful of 40 per cent nicotine sulfate to 1 ounce of soap in each gallon of water. Great care should be used in making the application to be sure that the undersides of the leaves are thoroughly covered. All grape leafhoppers,

whether adults or nymphs, which are hit with the above mixture, will be killed; but it is frequently the case that poor control of the insect is obtained because the spray is not thoroughly applied. To prevent the leafhoppers from escaping the spray, a boom should be used that will apply the spray to both sides of the leaves at once.

During the last few years, experiments conducted in some of the eastern states have shown that a 2 per cent nicotine dust, thoroughly applied, will give a very good control of these insects. The sprays or dusts should be applied first when the young leafhoppers become numerous on the under surface of the leaves. It is usually necessary to make one or two applications for the first-generation leafhoppers, depending somewhat on the season, and one or more applications for the second-generation. As the adult leafhoppers, like many of the other grape insects, pass the winter in shelters afforded by trash, weeds, or grasses, thoroughly cleaning up around the vineyards is of value in controlling these insects, and should be done as a general practice in the vicinity of grape vineyards.

References.—Calif. Agr. Exp. Sta. Circ. 126, 1915; *Ariz. Agr. Exp. Sta. Circ.* 146, 1924; *Rept. Entomol. Soc., Ont.*, 1922, p. 48, 1922; *N. Y.* (*Geneva*) *Agr. Exp. Sta. Bull.* 344, 1922; *U. S. Dept. Agr. Dept. Bull.* 19, 1914.

Grape Phylloxera[1]

Importance and Type of Injury.—This aphid is the most destructive grape pest known in the western United States and Europe. Fortunately for the grape growers of the eastern United States, it practically never causes serious damage in this section of the country. Within 25 years after this insect was introduced into France from America, about 1860, it had destroyed nearly one-third of the vineyards in that country. Small galls about the size of half a pea form on the leaf surface (Fig. 425), sometimes so numerous as practically to cover the entire leaf. The galls are open on the underside of the leaf. They contain many small, wingless, yellowish aphids. Numerous knots or galls form on the grape roots and rotting of the roots, yellowing of the grape foliage, and general decrease in vigor, or the death of the vines, result from injury by this insect.

Plants Attacked.—Grape.

Distribution.—General in North America where grapes are grown.

Life History, Appearance, and Habits.—The life history of this insect is extremely complicated, as there are four distinct forms of adults, besides the immature stages. Only a brief outline of its life history can be given. The winter is passed both as eggs attached to the canes of

[1] *Phylloxera vitifoliæ* Fitch, Order Homoptera, Family Phylloxeridæ.

the grape plants, and in the form of yellowish aphids on the nodules or galls on the grape roots (Fig. 426). The root-infesting forms become active, feeding on the roots as soon as growth starts in the spring. The eggs on the canes hatch in the spring after the foliage of the grape has come out and the yellow aphids developing from these eggs migrate to the leaves where they begin feeding. This injury to the leaf causes the formation of galls. As soon as the aphids have become full-grown, they give birth to living young inside the galls, and these young shortly begin forming other galls, several generations being passed on the leaf. Some of these leaf-inhabiting aphids drop to the ground, and burrow

FIG. 425.—Phylloxera galls on wild grape leaf. About natural size. (*From Slingerland and Crosby, "Manual of Fruit Insects." Copyright, 1915, by the Macmillan Company. Reprinted by permission.*)

beneath the soil to the roots, where they cause the formation of the root galls, and where they can live for a number of generations. Toward the fall of the year, winged forms are produced on the grape roots which leave the ground and lay eggs on the vines. These eggs hatch into males and true females, mating takes place, and each fertilized female lays a single egg, which remains on the cane during the winter.

Control Measures.—In the eastern United States, the form of Phylloxera which causes the galls on the leaves is very abundant, especially on some of the native grapes. The root-infesting form, while present, is very rare in the East and does not cause any serious damage. The insect is a native of eastern United States, and the grapes growing in that section have acquired practical immunity to its attack. The best-known and most effective remedy for combating this insect, is

the grafting of European grapes on root stalks native to eastern United States. This practically does away with any injury by the insect. Nearly all of the grapes sold in nurseries are grafted on native root stalks. In certain parts of California, and in Europe, where the European root stalks are used, the insect is controlled by flooding the vineyards at certain times during the season; also by soil fumigation with carbon bisulfide.

References.—*U. S. Dept. Agr. Dept. Bull.* 903, 1921; *U. S. Dept. Agr. Tech. Bull.* 20, 1928.

FIG. 426.—The grape phylloxera, *Phylloxera vitifoliæ* Fitch. *a*, galls on grape roots caused by feeding of the insects; *b*, gall much enlarged with aphids feeding; *c*, adult aphid, greatly enlarged; *d*, shed skin of the same. (*From Herrick, "Manual of Injurious Insects."*)

I. CURRANT INSECTS

FIELD KEY FOR THE IDENTIFICATION OF INSECTS INJURING CURRANTS

1. Scales up to 1/6 inch across, rounded in outline, with a grayish, nipple-shaped projection in the center are clustered or distributed singly over the bark of the currant. Lemon-yellow, sack-like, sucking insects on the bark under the scale. Infested plants often so heavily covered as to entirely coat the bark and kill the plants. *San José scale*, page 632.

2. Greenish, many-legged worms with black-spotted bodies, up to 1 inch in length, feed on the edges of the currant leaves. Injury usually starts about the time the plants come into full foliage, and is first noticeable in the center of the bushes. Black-bodied, wasp-like sawflies, about 1/4 inch in length, deposit pearly-white, elongated eggs, in rows, on the vines and midrib on the underside of the currant leaves. *Imported currant sawfly*, page 633.

3. Currant canes put forth undersized foliage in the spring, the tips of the canes often being dead and sometimes broken off. Burrows running the entire length of the cane, mainly in the pith, and containing yellowish, grub-like larvæ, about 1/2 inch long. Small round holes bored through the sides of the cane and in the early spring, covered with a silken web. Yellow clear-winged moths fly very actively about the currant bushes in the early summer. *Currant borer*, page 632.

4. Currant leaves show bright-red, cupped, or wrinkled areas. Numerous, small, greenish-yellow, somewhat flat-bodied aphids on the undersides of the curled and distorted leaves. Where injury is severe the leaves drop from the plants. *Currant aphid*, page 634.

5. Small whitish areas on the upper sides of the currant leaves. Leaves turn brown and drop. New growth of the currant wilts and dies. During late spring, bright-red wingless bugs, with black dots on the thorax, and yellow stripes on the sides, suck the sap from the leaf and new twig growth. Yellowish adult bugs, about 1/3 inch long by one-half as wide, with two distinct black stripes on each wing cover, feed on the currant leaves and new growth during late summer. *Four-lined plant bug*, page 635.

San José Scale

The San José scale is a serious pest of currants, and will soon kill out currant bushes if a plantation becomes infested and no treatment is given. It is easily controlled by the application of lime-sulfur or oil emulsions as recommended for the control of this insect on the apple. See page 539.

Fig. 427.—Imported currant borer, *Synanthedon tipuliformis* Linné, in its burrow ready to pupate. Enlarged one-half. (*From Slingerland and Crosby, "Manual of Fruit Insects," copyright, 1915, by the Macmillan Company. Reprinted by permission.*)

Imported Currant Borer[1]

Importance and Type of Injury.—This insect is of European origin but is now well distributed in America. It is almost sure to cause trouble in both commercial and garden currant plantations. Canes with yellowish undersized foliage appearing on them in the spring. Such canes usually die within 2 or 3 weeks. Dead canes usually with the tips broken off showing a burrow running nearly the entire length of the cane, partly in the pith and partly in the wood.

Plants Attacked.—Gooseberry, black elder, sumach, and currant. The insect is more destructive to the black than to the red currant.

Distribution.—Throughout North America.

Life History, Appearance, and Habits.—This insect passes the winter as nearly full-grown yellowish borers, or larvæ, about ½ inch long, which will be found inside the canes usually a short distance above the ground (Fig. 427). The larvæ feed a little in the spring, and eat an exit hole through the side of the cane which they cover with a silken web. They transform to the pupal stage inside the burrow a short distance from this exit hole. The adult insects emerge during June or July, in central Illinois. They are black-and-yellow, clear-winged moths, about ½ inch long, which one would readily mistake for small wasps. They are extremely active, flying with great rapidity. They deposit their eggs on the bark of the currant canes and the grubs hatching from these eggs bore into the canes, feeding on the pith and the wood. They are nearly full-grown by midfall, and remain in the canes during the winter as above stated.

Control Measures.—As practically no external feeding is done by this insect, and as they cannot be reached with contact sprays, the only effective method of control is to cut out and burn the infested canes. This can best be done shortly after the currant leaves appear in the spring, as it will then be very easy to distinguish the infested canes because of their weak, sickly appearance.

[1] *Synanthedon tipuliformis* Linné, Order Lepidoptera, Family Ægeriidæ.

The canes should be cut close to the ground and removed and burned before the last week in May, in the latitude of southern Illinois.

Reference.—Wash. Agr. Exp. Sta. Bull. 36, 1898.

Imported Currant Sawfly[1]

Importance and Type of Injury.—This insect is present on practically every currant bush each season, and control measures should be a part of

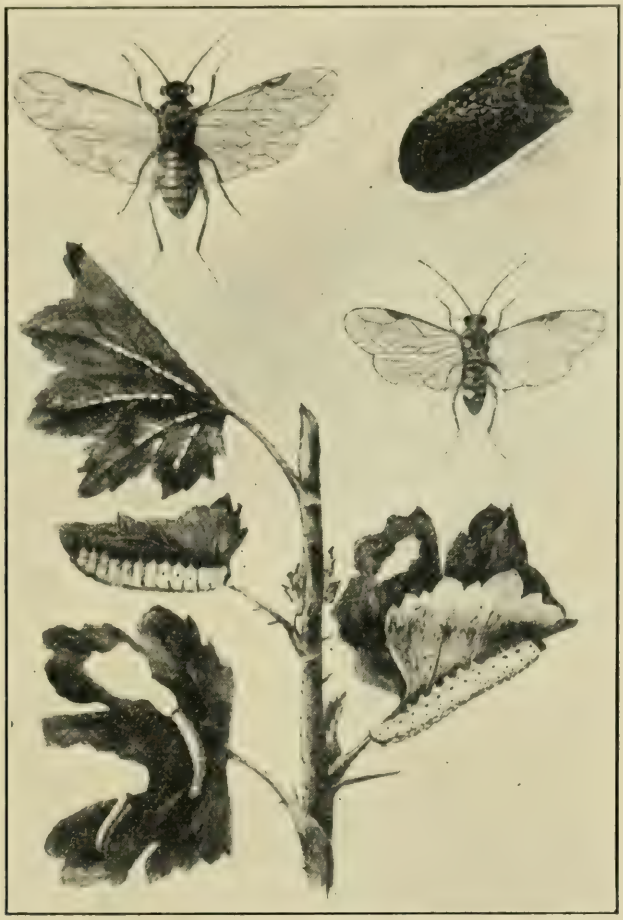


Fig. 428.—Imported currant sawfly, *Pteronidea ribesii* (Scopoli). Adult female at upper left, empty cocoon at upper right, male below it. Characteristic strings of eggs on veins on underside of upper leaf. Larvæ of several instars feeding below. Enlarged about one-half. (*From Ill. State Nat. Hist. Sur.*)

the regular routine of currant growing. Many-legged, smooth, greenish worms, with numerous black spots over their bodies, feed on the edges of the currant leaf (Fig. 428). When disturbed, the worms raise the front and hind part of their bodies from the leaf. When they are abundant the leaves are stripped from the currant, the injury usually starting in the thick foliage near the center of the plant.

Plants Attacked.—Currant and gooseberry.

[1] *Pteronidea ribesii* (Scopoli), Order Hymenoptera, Family Tenthredinidæ.

Distribution.—General over the United States and southern Canada. Imported from Europe about 1857.

Life History, Appearance, and Habits.—The winter is passed in a small, capsule-like cocoon on or near the surface of the ground in the larval or pupal stage. The adult sawflies (Fig. 428) are black, about ⅓ inch long, with the abdomen marked with light yellow. They deposit their white, flattened, shining eggs in rows on the veins and midribs of the underside of currant leaves shortly before the plant comes into full foliage (Fig. 428, *upper leaf*). The worms hatch just about the time that the currant leaves are full-grown, and feed along the margins of the leaves, consuming the entire leaf as they go. They feed for from 2 to 3 weeks, when they go to the ground and transform within their cocoons to the pupal stage. The second generation of the insect is usually not as numerous as the first, and appears on the vines during late June or July. A partial third generation occurs in the South. The larvæ of the later generations construct cocoons in the soil in which they pass the winter.

Control Measures.—These insects are very easily killed by any good stomach poison. For the first generation, the vines should be sprayed thoroughly with arsenate of lead, at the rate of 1 pound to 50 gallons of water, or 1 ounce to 3 gallons of water, applying this spray just about the time the currants come into full leaf. Dusting with arsenate of lead mixed with equal parts of hydrated lime is equally effective. If the second generation appears just before the fruit is ripe, a spray of hellebore, at the rate of 2 ounces to each gallon of water, should be used in order not to poison the fruit.

References.—*S. Dak. 10th Rept. Entomol.*, p. 26, 1919; *Can. Entomol.*, Vol. 52, p. 106, 1920.

Currant Aphid[1]

Importance and Type of Injury.—Currant leaves become krinkled or cupped (Fig. 429). The leaf surface becomes bright red in color, just above the points where the cupping occurs. Numerous small, greenish-yellow, somewhat flat-bodied aphids are found on the undersides of the curled and distorted leaves, most numerous inside the cups.

Plants Attacked.—Currants and sometimes gooseberry.

Distribution.—Throughout the United States and Canada.

Life History, Appearance, and Habits.—The currant aphid goes through the winter in the form of shining black eggs, which are found on the canes of the currant plants, particularly on the new growth. The young aphids hatch from these eggs soon after the leaves appear in the spring. They crawl to the leaves and suck the sap from the underside. Their feeding soon causes the distortion of the leaf described above. If very numerous, the infested leaves will drop from the plants. There are

[1] *Myzus ribis* Linné, Order Homoptera, Family Aphididæ.

a number of generations each season, all of those appearing during the summer consisting of females which give birth to living young as soon as they have become full-grown. In the fall of the year, these females give birth to males and females, which mate and deposit their eggs on the canes where the insect passes the winter.

Control Measures.—The aphids, being sucking insects, cannot be controlled by any stomach poisons. The best control consists in thoroughly spraying the undersides of the leaves early in the season with a nicotine solution, such as a 40 per cent nicotine sulfate, used 1 part to 800 parts of water, or ½ pint to 50 gallons of water. Where used with

Fig. 429.—Leaves curled and cupped by currant aphids. (*From Slingerland and Crosby, "Manual of Fruit Insects," copyright, 1915, by the Macmillan Company. Reprinted by permission.*)

water alone, soap should be added at the rate of 2 pounds of potash fish-oil soap to each 25 gallons of water. Arsenate of lead can be combined with this spray, controlling the sawfly and other leaf-feeding insects as well as the aphids. Dusting with a 2 per cent nicotine dust also is quite effective for the control of this insect. In spraying, or dusting, care must be used to get the material on the underside of the leaves and up into the ridges and cup-shaped depressions caused by the feeding of the aphids.

References.—N. Y. (Geneva) Agr. Exp. Sta. Bull. 517, 1924; *N. Y. (Geneva) Agr. Exp. Sta. Bull.* 139, 1897.

Four-lined Plant Bug[1]

Importance and Type of Injury.—Where this insect is feeding on the leaves of currants, small whitish dots appear on the upper sides of the leaves. If the insect is abundant, these areas come together, the leaf turns brown, and usually drops. New growth of the currant will sometimes wilt where this bug has fed upon it.

[1] *Pœcilocapsus lineatus* Fabricius, Order Hemiptera, Family Miridæ.

Plants Attacked.—General; gooseberry, rose, and many other shrubs and herbaceous plants.

Distribution.—General east of the Rocky Mountains.

Life History, Appearance, and Habits.—This insect passes the winter in the form of slender white eggs, about 1/16 inch long, which are inserted in slits in the canes of currants and other plants. Several eggs are generally laid at one place. They are forced into the cane at right angles to the long axis of growth, the tips of the eggs usually protruding from the cane. The eggs hatch from May to the latter part of June. The bright-red, crawling nymphs have black dots on the thorax and in the last stage, a yellow stripe on each side of the wing pads. They feed by inserting their beaks in the leaves and new twig growth and sucking the sap. They become full-grown in about a month to 6 weeks. The adult insects (Fig. 430) are nearly 1/3 inch

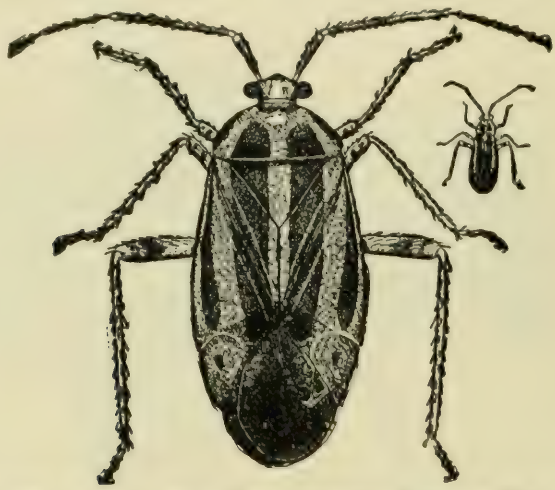


FIG. 430.—Four-lined plant bug, *Pœcilocapsus lineatus* Fabricius. Adult, natural size and enlarged. (*Reprinted from "Insect Pests of Farm, Garden and Orchard" by Sanderson and Peairs, published by John Wiley & Sons, Inc.*)

long, of a general greenish-yellow color, with four distinct black stripes down the wing covers on the back. In the fall, the female insects lay their eggs in the canes as above described. There is but one generation of the insect each year.

Control Measures.—As these insects are exceedingly active, they are somewhat hard to control. The best method is to spray with a strong contact poison such as a 40 per cent nicotine sulfate, used at the rate of 1 part to 600 parts of soapy water; or to dust with a 4 per cent nicotine.

Reference.—N. Y. (Cornell) Agr. Exp. Sta. Bull. 58, 1893.

J. GOOSEBERRY INSECTS

The gooseberry is injured by much the same insects as the currant. San José scale is often very destructive on gooseberry, but is not nearly so conspicuous on this plant as on the currant, the heaviest infestation often occurring close to the ground. If the scale is present in the vicinity of gooseberry plantations, they should be thoroughly sprayed, even though a casual examination does not show much scale on the canes. The imported currant sawfly is fully as destructive to the gooseberry as to the currant, and can be controlled by the same measures. The goose-

berry-fruit worms[1] feed on the pulp of the fruits, causing browning at the blossom end, premature coloring and often the drying up of the berries.

K. RASPBERRY INSECTS

FIELD KEY FOR THE IDENTIFICATION OF INSECTS INJURING THE RASPBERRY

1. Irregular rows of minute round punctures, each about the diameter of a pin and extending into the pith of the raspberry. The raspberry cane frequently dies above these punctures, or splits and breaks off during the winter. Cricket-like, pale-green insects, about 1 inch in length, with very long feelers and long hind legs crawl about over the plants and insert their eggs in the canes during the late summer. *Tree crickets*, page 637.

2. Fleshy enlargements or swellings of the raspberry canes, up to several inches long, and ½ inch or more in diameter. Slender, white-bodied grubs, up to ½ inch in length, feed on the pith of the canes in, or near, the swollen areas. Dull, bluish-black beetles, ⅓ inch in length by ¼ as wide, with a dull coppery-red area on the back just behind the head, are found on the canes during late spring and summer. *Red-necked cane borer*, page 639.

3. Buds and blossoms of the raspberry with numerous holes eaten in them; leaves partly skeletonized; whitish grubs about ¼ inch long, feed inside the ripening fruit. Small light-brown beetles about ⅛ inch in length feeding on the tender leaves and newly opening buds. *American raspberry beetle, Byturus unicolor* Say (see *Ohio Agr. Exp. Sta. Bull.* 202, 1909).

4. Raspberry leaves with pale-green, spiny, many-legged worms feeding on the edges of the leaf. Insects more abundant about the time raspberry comes into full foliage, sometimes nearly stripping the plants of leaves. *Raspberry sawfly, Monophadnoides rubi* Harris (see *N. Y.* (*Geneva*) *Agr. Exp. Sta. Bull.* 150, 1898).

5. Bases of raspberry plants, particularly on the more heavily-shaded parts of the stem, covered with white, scurfy-appearing scales. Reddened areas on the bark around the points where the scale is attached. These scales are about ⅕ inch across when full-grown, rounded in outline and flattened. In the winter many reddish eggs will be found beneath the protecting scale. *Rose scale, Aulacaspis rosæ* Bouché (see Essig, "Insects of Western North America," p. 307, 1926).

Tree Crickets[2]

Importance and Type of Injury.—The insects known as tree crickets (Fig. 432) sometimes cause injury to tree and bush fruits. Small round holes about the diameter of a pin (Fig. 431) are drilled singly in the twigs or brambles. In each hole, which extends into the cambium or sapwood, the insect deposits a single pale yellow egg, about ⅛ inch long. The punctures are usually made in a single row along one side of the cane or stem, sometimes as many as 50 to 75 in a row, and about 25 to the inch. These egg punctures often serve as the entrance points for tree and bramble diseases. Canes frequently die above these punctures, and

[1] *Zophodia grossulariæ* Riley and *Zophodia franconiella* Hulst, Order Lepidoptera, Family Pyralididæ

[2] *Œcanthus niveus* DeGeer, *Œcanthus nigricornis* Walker, and others, Order Orthoptera, Family Gryllidæ.

where they are numerous the canes split and break off. The adult insects are sometimes very injurious by eating holes in ripe fruits.

Plants Attacked.—Apple, prune, plum, peach, cherry, raspberry, loganberry, blackberry, and others.

Life History, Appearance, and Habits.—The insects winter in the egg stage in twigs or brambles, the young hatching in the spring. The

1 2 3 4

FIG. 431.—Egg punctures of a tree cricket in raspberry canes. (*From N. Y. (Geneva) Agr. Exp. Sta. Bull.* 388.)

pale-green slender nymphs (Fig. 80) feed on the foliage of various plants or on small, sluggish insects, fungi, pollen, or ripe fruits. They grow rather slowly, reaching the adult stage in late summer. The adults have somewhat the appearance of a cricket, but are pale green in color and have a longer, more slender body and smaller heads. The antennæ, or feelers, projecting from the front of the head, are much longer than the body. The males have the wings flat, with stiff veins and adapted to making sounds. The songs of the males in late summer are described as a series of short, clear, musical whistling notes, indefinitely repeated,

often synchronized, and varying in frequency with the temperature. The females deposit their eggs in the fall, and there is only one generation each year.

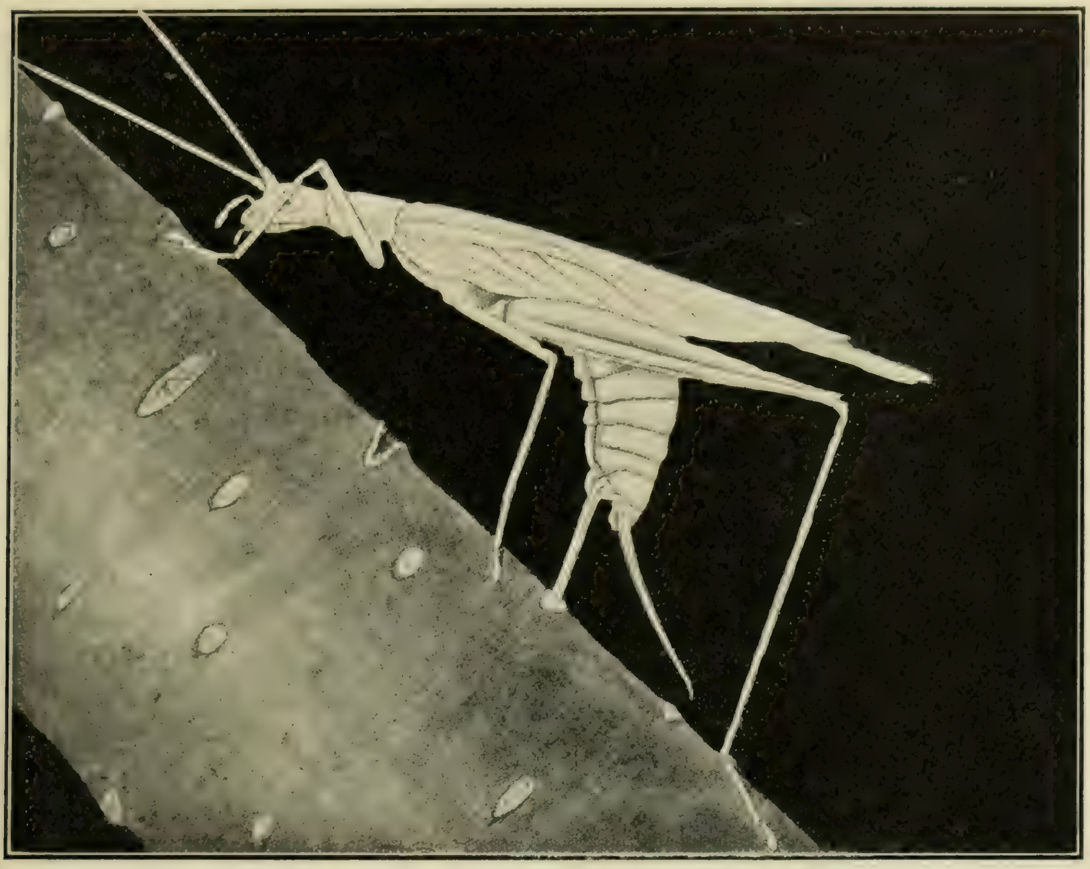


FIG. 432.—The snowy tree cricket, *Œcanthus niveus* De Geer, characteristic posture of female in act of laying eggs. (*From N. Y. (Geneva) Agr. Exp. Sta. Bull.* 388.)

Control Measures.—Spraying or dusting with arsenicals in early summer, while the crickets are young, has given complete control. Burning old canes after the last crop has been removed aids in control.

References.—*N. Y. (Geneva) Agr. Exp. Sta. Bull.* 388, 1914; *Ore. Agr. Exp. Sta. Bull.* 223, 1926.

RED-NECKED CANE BORER[1]

Importance and Type of Injury.—The injury caused by this beetle is shown by enlargements or swellings of the raspberry or blackberry canes (Fig. 433). The canes frequently die and sometimes break off at the point where the swelling occurs.

Plants Attacked.—Raspberry, blackberry, and dewberry.

Distribution.—Eastern United States.

Life History, Appearance, and Habits.—The winter is passed in the form of a slender white grub inside the pith of the raspberry cane. These grubs are about ½ inch in length. In the spring they complete their growth, change inside the stem to the pupal stage, and emerge during May and June as dull, bluish-black beetles, with a metallic lustre, about ⅓ inch in length by one-fourth as wide, with a coppery-red

[1] *Agrilis ruficollis* Fabricius, Order Coleoptera, Family Buprestidæ.

or brassy prothorax. These beetles lay their eggs in the bark of the cane, usually near the base of the leaf. The young larvæ burrow upward in the sapwood, and also around the cane, sometimes making several girdles, and causing the formation of the galls or swellings. There is but one generation of the insect each year.

Fig. 433.—Section of blackberry cane showing gall or swelling caused by larva of red-necked cane borer. (*From U. S. D. A. Farmers' Bull.* 1286.)

Control Measures.—The only method of control is to cut out the infested canes during the winter, burning the galls, thus destroying the young larvæ within them.

Reference.—U. S. Dept. Agr. Farmers' Bull. 1286, 1922.

L. BLACKBERRY INSECTS

The blackberry is comparatively free from insect injuries. It is infested to some extent by the rose scale, reference to which has been made under Raspberry, page 637. The canes are occasionally punctured by tree crickets (p. 637). The larva of a wasp known as the blackberry leaf miner,[1] works in the leaves, but is rarely abundant enough to cause serious injury. The raspberry sawfly (p. 637), also attacks the blackberry, and can be controlled by the same methods recommended for other sawflies on p. 634. The canes of the blackberry are occasionally injured by the larvæ of the red-necked cane borer (p. 639), which causes irregular swellings or galls along the canes. The insect is rarely numerous enough to be considered of any economic importance. Leafhoppers (p. 627) and mites (p. 448) sometimes become thick enough on the foliage to cause a whitening of the leaves.

M. STRAWBERRY INSECTS

FIELD KEY FOR THE DETERMINATION OF INSECTS INJURING THE STRAWBERRY

A. Insects injuring the roots:

1. Small, white, brown-spotted grubs, about ⅛ inch in length, feeding on the roots of strawberries during May and June. Infested plants are weakened and with poorly colored foliage. Brownish or coppery-colored beetles, about ⅛ inch long, feeding on the foliage of strawberries during the early fall. *Strawberry rootworms,* page 643.

[1] *Metallus rubi* Forbes, Order Hymenoptera, Family Tenthredinidæ. (See *Del. Agr. Exp. Sta. Bull.* 87, 1910.)

2. Large white grubs, up to 1 inch in length, with brown heads, usually holding the body in a curved position, and with distinct, well-developed, slender legs, feed on the roots of strawberries from early spring to early fall. *White grubs*, page 646.

3. Strawberry plants lacking in vigor, foliage of a pale color, the fruit drying up, or failing to mature properly. Roots of the injured plants covered with dark, bluish-green aphids, their slender beaks inserted in the roots, from which they suck the sap. Usually attended by small brown ants. Aphids of the same description feeding on the leaves during early spring. *Strawberry root louse*, page 645.

B. Insects injuring the crown of the plant:

1. White, thick-bodied grubs, about ⅕ inch in length, boring in the crowns of the strawberry plant. Crown of the plant eaten out so that it dies or is so weakened that very few runners or new growth are produced. Reddish-brown snout beetles, about ⅙ inch in length, shelter under litter or about the plants in strawberry fields during the winter. *Strawberry crown borer, Tyloderma fragariæ* Riley (see *Tenn. Agr. Exp. Sta. Bull.* 128, 1923).

2. Strawberry plants eaten off close to the ground by curved-bodied, light, brown-headed grubs, about ⅕ inch long. Grubs most abundant during late spring and again during the late summer. Black beetles, ⅙ inch long, with a short, blunt snout protruding from the front of the head, clustered about the bases of strawberry plants and sometimes feeding on the leaves. *Strawberry crown girdler*, page 644.

C. Insects injuring the leaves:

1. Very small, green or metallic-blue, jumping beetles, less than ⅙ inch across, feeding on the strawberry plants early in the spring. Leaves riddled with small round holes, often drying up and turning brown. *Strawberry flea beetle*, page 645.

2. Small greenish or bronze caterpillars folding or rolling together the strawberry leaves and feeding within the rolled portion. Heavily infested plants have a whitish appearing foliage. Injury occurs from early spring until early fall. Small grayish-brown moths, about ¼ inch long, the wings marked with wavy bands of light brown, fly about strawberry beds from April to September. *Strawberry leaf rollers*, page 641.

3. Grayish, plump-bodied snout beetles, about ½ inch long, the wing covers crossed by two light bands, bent down at the end and terminating in an acute angle, and most of the body covered with small flattened scales, sometimes defoliate the plants. *Imbricated snout beetle*, page 533.

D. Insects injuring the buds and fruits:

1. Buds and newly formed fruit of the strawberry dried up on the partly severed stems, or entirely eaten off. This injury is caused by dark, reddish-brown, snout beetles, from 1⁄12 to ⅛ inch long, which make punctures in the buds, in which they insert eggs. Very small, legless, white, soft-bodied grubs, feed within the strawberry buds. *Strawberry weevil*, page 643.

Strawberry Leaf Rollers[1]

Importance and Type of Injury.—Small greenish or bronze caterpillars fold or roll the strawberry leaves (Fig. 435), fastening them together and feeding within. The leaves have a brown appearance and much of the foliage is killed. Heavily infested beds have a whitened or grayish appearance instead of the usual green of healthy strawberry plants.

Plants Attacked.—Strawberry, blackberry, and raspberry.

[1] *Ancylis comptana* Fröhlich and *Archips obsoletana* Walker, Order Lepidoptera, Family Tortricidæ.

Distribution.—United States ranging west to Colorado and Idaho, and southern Canada.

Life History, Appearance, and Habits.—The winter is passed in the larval and pupal stages, the pupæ inside of silken cocoons in the folded leaves, and the larvæ in silken shelters under trash on the surface of the ground. In the spring of the year, the larvæ transform to pupæ and a little later emerge as small, grayish or brownish moths, a little more than an inch in length. The wings are marked with wavy bands of light and dark color. In southern Illinois, the moths are abroad in April, and in the northern part of the state by the middle of May or a little earlier.

FIG. 434.

FIG. 435.

FIG. 434.—Larva of the obsolete-banded strawberry leaf roller, *Archips obsoletana* Walker, on leaf. Three times natural size. (*From Slingerland and Crosby "Manual of Fruit Insects," copyright,* 1915, *by the Macmillan Company. Reprinted by permission.*)

FIG. 435.—Strawberry leaf roller, *Ancylis comptana* Fröhlich. Leaves folded by larvæ, slightly reduced. (*From Iowa Agr. Exp. Sta. Bull.* 179.)

They lay their eggs on the undersides of the strawberry leaves. These eggs hatch in about 1 week and the caterpillars coming from them (Fig. 434) feed on the upper side of the leaves for a few days, drawing the leaves together and holding them with fine silken threads. They feed for about 1 month and then transform into brown pupæ inside the folded leaves. There are probably three generations each year throughout most of its range.

Control Measures.—Spraying the plants with arsenate of lead at the rate of 2 pounds to 50 gallons of water or of Bordeaux mixture, is an effective control. The spray must be applied, however, before the leaves have become folded to any extent, as the poison will not be effective against the leaf rollers after they have constructed their silken cases. The numbers of the insect may be kept down if the strawberry beds are

mowed close to the ground and burned over shortly after the fruit is picked.

References.—Neb. State Entomol. Circ. 7, 1908; *Iowa Agr. Exp. Sta. Bull.* 179, 1918. *Iowa Agr. Exp. Sta. Circ.* 110, 1928.

Strawberry Weevil[1]

Importance and Type of Injury.—The work of this beetle kills buds and fruits, leaving them hanging on partly severed stems (see Fig. 5, *E*).

Plants Attacked.—Strawberry, wild blackberry, dewberry, and cinquefoil.

Distribution.—Eastern United States.

Life History, Appearance, and Habits.—This insect passes the winter in the form of a dark, reddish-brown, snout beetle from $\frac{1}{12}$ to $\frac{1}{8}$ inch

Fig. 436.—Strawberry weevil, *Anthonomus signatus* Say, on stem of strawberry. About four times natural size. *(From Ark. Agr. Exp. Sta. Bull.* 185.)

long (Fig. 436), sheltered under trash. These adults become active early in the spring, about the time the strawberries are coming into bloom. The adult beetle makes a puncture in the strawberry bud with her long beak, and in this inserts an egg. She then crawls down and girdles the stem of the bud. The young grubs, which are legless, white, and soft bodied, feed within the buds and after about 4 weeks change within the bud to a pupal stage. The adults emerge a little before midsummer. They feed for a short time and then go into hibernation quarters about midsummer and remain there until the following spring.

Control Measures.—Spraying with arsenate of lead and Bordeaux mixture at the rate of 2 pounds of arsenate of lead in 50 gallons of 4-6-50 Bordeaux is fairly effective as a control measure. The spray should be applied just before the strawberries start to bloom.

References.—Tenn. State Bd. of Entomol. Bull. 30, 1919; *N. J. Agr. Exp. Sta. Bull.* 324, 1918; *Ark. Agr. Exp. Sta. Bull.* 185, 1923.

Strawberry Rootworms[2]

Importance and Type of Injury.—There are several species of small beetles, the young of which are quite injurious to strawberries. Small, white, brown-spotted

[1] *Anthonomus signatus* Say, Order Coleoptera, Family Curculionidæ.

[2] *Paria (Typophorus) canella* (Fabricius), *Colaspis brunnea* Fabricius and *Graphops pubescens* Melsheimer, Order Coleoptera, Family Chrysomelidæ.

grubs feeding on the roots of the strawberries during May, June and July. These grubs (Fig. 437) are about ⅛ inch in length, and are very much smaller than the common white grub. The foliage of strawberries is destroyed by small bronze-brown or copper-colored adult beetles, about ⅛ inch long (see also pp. 717 and 313).

Plants Attacked.—Strawberry, raspberry, grape, rose, and many other plants.

Distribution.—Over most of the United States.

Life History, Appearance, and Habits.—These insects pass the winter as full-grown beetles (Fig. 438). They come out of their winter shelters during April or May. The females deposit their eggs in the ground near the plants. The young grubs hatching from them feed on the roots for about 3 months, becoming full-grown during August, and transforming to a pupal stage and later to the adult beetle. The beetles do considerable feeding on the foliage of the strawberry during the early fall.

Control Measures.—These insects can be effectively controlled by spraying with arsenate of lead at the rate of 2 pounds to 50 gallons of water, applied as soon as the beetles are seen on the foliage of the strawberry in the late spring, or in the fall. The time of appearance will vary with the season.

FIG. 437.—Strawberry rootworm, *Paria canella* (Fabricius). Larva or grub, about fifteen times natural size. (*From U. S. D. A. Farmers' Bull.* 1344.)

FIG. 438.—Adult of the strawberry rootworm *Paria canella* (Fabricius). About ten times natural size. (*From U. S. D. A. Farmers'Bull.* 1344.)

References.—*U. S. Dept. Agr. Farmers' Bulls.* 1344, 1923 and 1362, p. 59, 1922; *Thirteenth Rept. Ill. State Entomol.*, p. 159, 1883. *U. S. Dept. Agr. Dept. Bull.* 1357, 1926.

STRAWBERRY CROWN GIRDLER OR ROOT WEEVIL[1]

Importance and Type of Injury.—Strawberry plants dying, and eaten off close to the ground, by fat, curved grubs with light brown heads.

Plants Attacked.—Strawberry and many other plants.

Distribution.—Northen United States and Canada.

Life History, Appearance, and Habits.—The insect passes the winter in both the larval and adult stages. The adults are nearly black beetles, about ¼ inch long or a little less, having short blunt snouts protruding from the front of their heads. The grubs, or larvæ, are white, legless, ¼ inch long, with light-brown heads, and hold their bodies in more or less of a curved position. The grubs begin feeding as soon as the weather becomes warm in the spring and about the same time the beetles leave the shelters in which they have passed the winter and gather in the strawberry beds.

[1] *Brachyrhinus ovatus* Linné, Order Coleoptera, Family Curculionidæ.

The wing covers of the beetles are tightly grown together and the insect is unable to fly. In southern Illinois, the insect is most abundant in the adult stage during May and June, and again in late July and August. The female beetles lay small white eggs among the roots of the strawberry plants, these eggs hatching into the grubs above described. There are probably two generations a year in the latitude of Illinois.

Control Measures.—Spraying with an arsenical is a very effective measure of control. Rotating the strawberry beds to new ground which has not had strawberries on or near it for at least 1 year is of value. Recent work in Tennessee has shown that this insect may be kept out of the strawberry fields by constructing a barrier of tarred boards around the new fields. In the west a poison bait of ground dried apple and an arsenical is highly recommended.

References.—*Me. Agr. Exp. Sta. Bull.* 123, 1905; *Dom. Can. Dept. Agr. Pamphlet* 5, n. s. 1922; *Wash. Agr. Exp. Sta. Bull.* 199, 1926.

Strawberry Flea Beetle[1]

Importance and Type of Injury.—Very small, metallic-blue beetles feed on the foliage of the strawberry plants. The leaves are riddled with large numbers of small round holes, often drying up and browning around these holes.

Plants Attacked.—The beetles lay their eggs on strawberry, evening primrose, and other plants of the same family.

Distribution.—Throughout the United States and Canada.

Life History, Appearance, and Habits.—These beetles, in common with many other kinds of flea beetles, hibernate as adults. They emerge early in the spring, and their principal damage is done before the strawberry plants bloom. There are from one to two generations a year, the larger number occurring in the South.

Control Measures.—Thorough spraying of the strawberry plants with 4-6-50 Bordeaux mixture, applied whenever the insects are abundant, is very effective. Usually this application should be made about a week before the strawberries bloom.

Strawberry Root Louse[2]

Importance and Type of Injury.—Strawberry plants are lacking in vigor, the foliage of a pale color. The fruit dries up or fails to mature properly.

Plants Attacked.—Strawberry.

Distribution.—United States east of the Rocky Mountains.

Life History, Appearance, and Habits.—These insects pass the winter in the form of black shining eggs which are attached to the leaves and stems of the strawberry plant. The eggs hatch early in the spring into dark, bluish-green aphids (Fig. 439), which feed on the new leaves of the strawberry. Wherever these lice become abundant, they are soon found by colonies of the brown corn field ant, and are carried by these ants to the strawberry roots, where they feed by sucking the sap from the roots. There are a number of generations of the insect during the year. All of those occurring in the field during the summer are females

[1] *Haltica ignita* Illiger, Order Coleoptera, Family Chrysomelidæ.

[2] *Aphis forbesi* Weed, Order Homoptera, Family Aphididæ.

and reproduce by giving birth to living young. On the approach of cold weather in the fall, winged females are produced. These make their way to the leaves of the plant and there give birth to the sexual females and males. After mating, these true females lay the winter eggs above described.

Control Measures.—No very effective control measure is known. In setting new beds, uninfested plants should be selected, and the ground, wherever beds are set, should be given a thorough and deep cultivation

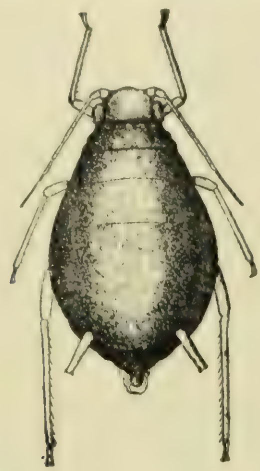


FIG. 439.—Wingless adult female of the strawberry root louse, *Aphis forbesi* Weed. Greatly magnified. (*From Ill. State Nat. Hist. Sur.*)

in the early spring, to break up and drive out the ants which may be in the soil.

References.—*N. J. Agr. Exp. St.. Bull.* 225, 1909; *Del. Agr. Exp. Sta. Bull.* 49, 1900.

WHITE GRUBS[1]

White grubs or grub worms are among the insects most commonly injurious to strawberries. Large white grubs with brown heads feed on the roots of the strawberry plants, causing the plants to die over areas of varying size. It is practically impossible to clean a strawberry bed, once infested with white grubs, without plowing up the bed. In setting new patches, ground should be selected that has been in some clean-cultivated crop for 1 or 2 years previously; as the June beetles prefer to lay their eggs in grass land or land with a heavy growth of grassy weeds. If possible, strawberry beds should be located at some distance from the trees on which the beetles feed and near which they usually lay their eggs. Thorough cultivation of the soil in the spring before the plants are set will be of some benefit, but will not clean all of the grubs out of the soil (see further discussion of white grubs on page 306).

[1] Many species of *Phyllophaga*, Order Coleoptera, Family Scarabæidæ.

CHAPTER XVIII

CITRUS INSECTS

No attempt is made in this publication to cover thoroughly the various species of insects which cause injury to citrus trees. A few of the more important ones are treated. For more complete information, the reader is referred to the various publications put out by the states where citrus is extensively grown.

References.—*U. S. Dept. Agr. Dept. Bull.* 907, 1920; *Fla. Agr. Exp. Sta. Bull.* 183, 1926; 148, 1918; 126, 1915; *U. S. Dept. Agr. Farmers' Bull.* 1321, 1923; 933, 1918; 862, 1917; 674, 1915; *Calif. Agr. Exp. Sta. Bull.* 214, 1911; *Calif. Fruit Growers Exchange, Bureau of the Pest Control, Bull.* 5, 1928; Essig, "*Insects of Western North America*," pp. 269–322, 1926.

FIELD KEY FOR THE DETERMINATION OF INSECTS INJURING CITRUS FRUITS

A. *Motionless insects, covered by a firm, waxy shell, on fruits, leaves or twigs:*

1. Foliage of trees showing yellow leaves or brown areas which break out of the leaves. Fruits uneven in color, with elongate, oyster-shell-shaped scales attached to the skin of the fruit. Many dead twigs. *Long scale or purple scale*, page 649.

2. Leaves entirely yellow or spotted with yellow. No honeydew on the leaves or fruits:

(*a*) Many yellow spots on the fruits. Entire branches of trees covered with a thin coating of circular yellowish or reddish scales, about $\frac{1}{12}$ inch in diameter. *California red scale*, page 650.

(*b*) A sprinkling of purplish-red round scales on leaves and fruit only. *Florida red scale*, page 650.

3. Foliage of trees somewhat discolored. Fruits and leaves covered with honeydew or a black, sooty growth of mold. Bodies of insects not covered with a separable shell:

(*a*) Nearly round scales, about $\frac{1}{5}$ inch across, of a brown or blackish color, often with a raised "H" on the back, are found over the twigs, leaves, and fruits. *Black scale*, page 652.

(*b*) Oval brownish scales on twigs and leaves, up to $\frac{1}{6}$ inch long and very flat. *Soft brown scale*, page 704.

(*c*) Large white, cottony, fluted objects, nearly $\frac{1}{2}$ inch long, on the twigs. Smaller, oval, yellowish-brown scales on the leaves. *Cottony cushion scale*, page 57.

B. *Insects usually more or less active; not covered with a separable shell:*

1. Leaves of trees showing pale spots and with light webs on their under surface. Minute red or yellow mites on the leaves or fruits. Fruits with a grayish or silvery sheen to the skin. Fruit drops. *Red spiders*, page 653.

2. Flowers and buds show retarded growth and the new growth distorted. Many, tiny, slender, dark or yellowish insects among buds and flowers. Skins of fruits show erect shallow scabs or smooth scars. *Thrips*, page 654.

3. Masses of cottony white material covering flat, oval, purplish, soft-bodied bugs on leaves or at the angles where fruits touch. Fruits coated with very sticky honeydew or black sooty mold. *Mealy bugs*, page 656.

4. Foliage of trees covered with honeydew or blackened with a heavy growth of sooty mold. Fruits undersized or of poor color. At certain seasons, very small white insects fly from the tender growth of trees when disturbed. Small pale-green, short-oval, flat, scale-like nymphs fixed to the underside of the leaves. Brown, bright-red, or yellow fungi often growing on the bodies of the nymphs. *Whiteflies*, page 657.

5. Foliage more or less tightly curled and more or less covered beneath with soft-bodied plant lice. *Aphids*, page 442.

6. Fruits russet-brown or, on grape fruit, chamois color, but smooth. *Rust mite*, page 658.

Citrus Scale Insects

The scale insects of citrus are probably the most destructive of any group of insects which attack these trees. As with the greenhouse scales, the citrus scales can be divided into three classes, armored scales, unarmoured scales, and mealy bugs.

Armored Scales

In this class of scales, a protective covering of wax is secreted from the body of the insect to form two protective scales, one above and the other beneath the body of the scale. The upper covering is thick and hard, the lower plate, or scale, is very thin and delicate, fitting closely to the surface of the plant where the insect is feeding. In this class of scales, the eggs are laid under the protective scale, or in some cases, the young are born alive. In either case, the young scales move about for a short time, select a favorable location on their food plant, and there insert their beaks, and, in the case of the females, do not move for the remainder of their lives. On starting to feed, they begin to secrete fibers of wax, which form the covering or scale over the body. The insects molt or shed their skins very shortly after beginning to suck the sap, and at this first molt lose their legs. The females later molt a second time and become adults; while the males after a further metamorphosis, develop into small two-winged adults, which are incapable of feeding. They mate with the females and die very shortly thereafter. The female after being fertilized increases quite rapidly in size and produces her eggs, or begins giving birth to living young. The scales that attack citrus develop more slowly during the colder periods of the year, but all stages of these insects can usually be found on trees at any season. Some of the most destructive of the armored scales are the purple scale, the long scale, the yellow scale, and the orange, or red, scales.

Purple Scale[1]

Importance and Type of Injury.—The foliage of trees infested by the purple scale turns yellow about the areas where the scales are feeding. In Florida these yellow areas may turn brown and break out, making holes through the leaves. Fruit attacked by this scale is stunted, ripening is delayed, the coloring of the fruit is very uneven, and flavor is affected. The scales are difficult to remove from the fruit before marketing, requiring a vigorous scrubbing to detach. Their feeding also permits the entrance of various fungi.

Fig. 440.—The purple scale, *Lepidosaphes beckii* (Newman), male and female scales on orange leaf, about five times natural size. (*From Essig, "Insects of Western North America," copyright, 1926, by the Macmillan Company. Reprinted by permission.*)

Distribution.—This insect is the most important pest of orange groves in Florida. It is of considerable importance in California, but in that state is mainly confined to some of the coastal sections.

Plants Attacked.—The purple scale is primarily a pest of citrus fruit, and particularly of the orange and grapefruit. It also occurs on avocado, croton, eucalyptus, fig, olive, yew, and other plants.

Life History, Appearance, and Habits.—The female scale deposits her eggs beneath the waxy coating, dying soon after her full quota of eggs are laid. These eggs hatch in from 2 to 3 weeks. The young pale-white scales crawl about the bark for a short time. In Florida they are

[1] *Lepidosaphes beckii* (Newman), Order Homoptera, Family Coccidae. The long scale, *Lepidosaphes gloveri* (Packard), is very similar to the purple scale but is much narrower and straighter.

said to be strongly repelled by light, and to seek the shaded part of the tree and fruit as a place for inserting their beaks before starting to feed. They are, however, repelled by total darkness, seeking a position somewhat intermediate between that of exposure to sunlight and the most heavily shaded parts of the tree. The first molt occurs in about 18 or 20 days, after which the insect forms a thicker scale which is of a reddish or purplish-brown color. The full-grown scale is about 1/8 inch long, and shaped like an oyster shell (Fig. 440). After the insects have fed for about 2 months, the males change to two-winged, active insects, fly about, and mate with the females, which shortly begin to deposit their eggs. Each female lays from 40 to 50 eggs underneath her protective scale. In Florida, there are three main generations a year.

Control Measures.—In Florida, it has been found possible to control the purple scale and the whitefly by the same applications. The more thorough spraying, however, is usually required for the control of the purple scale. The Florida Experiment Station recommends the following control measures: Spraying with an oil emulsion made after the formula:

Fish-oil soap	8 pounds
Paraffin oil	2 gallons
Water	1 gallon

or one composed of:

Fish-oil soap	2 pounds
Light-grade lubricating oil	2 gallons
Water	1 gallon

The stock emulsion should be used at a 1 to 2 per cent strength in soft water. The latter spray should be mixed and prepared according to the recommendations given for the preparation of oil emulsions on page 250. Under average conditions, the spray should be applied in May and again in September or early October. Two sprays are all that are generally required to keep down this scale, if they are applied with sufficient thoroughness. In California, and to a lesser extent in Florida, fumigation with either liquid hydrocyanic acid or calcium cyanide is used.

Reference.—Calif. Agr. Exper. Sta. Bull. 226, 1912.

California Red Scale[1]

Importance and Type of Injury.—This is one of the worst of the armored scales occurring on citrus trees in California. In Florida, the scale is of comparatively little importance. A similar scale known as the Florida red scale,[2] is of much importance in that state, where it performs a similar injury except that it attacks the leaves and fruit only. No

[1] *Chrysomphalus aurantii* (Maskell), Order Homoptera, Family Coccidæ.

[2] *Chrysomphalus aonidum* (Linné), Order Homoptera, Family Coccidæ (Fig. 472).

injury from the secretion of honeydew occurs to trees where this scale is present, but as the California red scale infests all parts of the trees, including the leaves, twigs, and fruit, its feeding is often a serious matter. Infested trees have the leaves spotted with yellow or entire leaves turning yellow and yellow spots on the fruit, but not the marked discolorations that often appear with other scales. The entire bark of twigs and branches may be covered by round, or nearly round, distinctly reddish scales up to about $\frac{1}{16}$ inch in diameter (Fig. 441).

Plants Attacked.—Primarily citrus, but it also infests acacia, eucalyptus, fig, grape, privet, quince, rose, English walnut, willow, and many other plants.

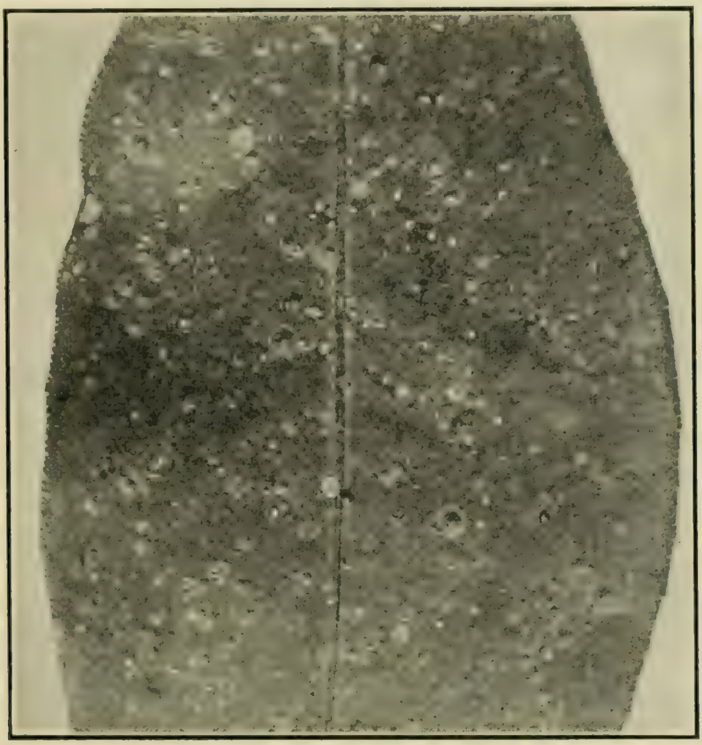


FIG. 441.—The California red scale, *Chrysomphalus aurantii* (Maskell), showing mature males and females and young; about natural size. (*From E. O. Essig, University of California.*)

Distribution.—Generally abundant in the coastal, citrus-growing regions of California, and in a number of the citrus districts in Florida. It also occurs in the West Indies and other parts of the world where citrus is grown.

Life History, Appearance, and Habits.—The life history of this scale somewhat resembles that of the San José scale on deciduous fruits. The young scales are born at the average rate of two or three a day for a period of about 2 months during the summer. Small numbers of young are born during warmer periods in winter months; but very few, if any, are produced during the colder weather. The young insects feed for from $2\frac{1}{2}$ to $3\frac{1}{2}$ months before reaching maturity. The males develop

into yellowish, minute, two-winged insects, which mate with the females and die, the mated females living for about 2 months longer, and during this time reproducing. There may be as many as four generations a year in southern California.

Control Measures.—The control of this scale is the same as that of the other armored scales, and consists of spraying with oil emulsions, or fumigating with hydrocyanic acid gas. The control will vary with the conditions in the orchard. For the best method to follow, refer to the special publication on this subject.

Reference.—*Calif. Agr. Exp. Sta. Bull.* 222, 1911.

Unarmored Scales

The unarmored scales are often called also soft scales and are, as a class, larger than the armored scales. No true scale of wax is formed separate from the body wall. The protective covering is the body wall, which is hardened with chitin. Both sexes move about during the early part of their lives, but the females cannot crawl after the eggs have formed. These scales discharge quantities of honeydew from their bodies, and the sooty fungus that grows in the accumulations of this honeydew often causes nearly as much injury as the feeding of the scales. The black scale, the soft brown scale, and the hemispherical scale are typical examples of this class.

Black Scale[1]

Importance and Type of Injury.—This scale is generally considered the most destructive insect pest of citrus in California. It causes severe damage to citrus in many other parts of the world, with the exception of Florida, where it is a very minor pest of oranges. The principal damage is caused, not by the feeding of the insect, but by the sooty mold fungus, which grows on the honeydew given off by this scale. This fungus makes it necessary to wash all fruits from badly infested groves.

Trees Attacked.—Orange, grapefruit, lemon, plum, almond, apple, pear, apricot, beech, fig, grape, pepper tree, oleander (the most common host in Florida), rose, English walnut, and a number of other plants.

Distribution.—All of the principal citrus-growing regions of the world.

Life History, Appearance, and Habits.—The winter is passed in all stages of growth, but mainly as partly grown females. Most of the overwintering scales become full-grown early in the spring. The full-grown females are nearly hemispherical in shape, being about $\frac{1}{5}$ inch across, and from $\frac{1}{25}$ to $\frac{1}{8}$ inch thick (Fig. 442). They deposit an average of 1,500 eggs. The eggs, which are about $\frac{1}{80}$ inch in length, are white at first, later changing to orange. Most of the eggs are laid during

[1] *Saissetia oleæ* Bernard, Order Homoptera, Family Coccidæ.

the spring months. The eggs hatch in about 20 days. The young remain beneath the parent scale for some hours, and then emerge and crawl about, but always start feeding within 3 days. Most of the young settle on the leaves or new growth. When partly grown, most of the scales migrate to the twigs and branches. From 8 to 10 months are required for the scales to complete their growth. The males go through a pupal stage, and in the adult stage are active, two-winged insects. There is probably only one complete generation in a year.

Control Measures.—Under most conditions, black scale has been controlled by fumigation with hydrocyanic acid, the dosage varying with the infestation and the condition of the orchard. During the past several years, combinations of oil emulsion, made with sulfinated oils emulsified with a colloidal emulsifier, and lime-sulphur and calcium caseinate, have given very good control of the black scale. In most of the areas of southern California where the black scale has apparently developed resistance to fumigation, spraying has given much better control. The formula giving the best results is emulsified oil 3 to 6 gallons (depending on the kind used); lime-sulphur, 3 to 4½ gallons; calcium caseinate 3 pounds; water 300 gallons.

No serious burning has resulted from such sprays applied in the fall. Citricola scale and red spider also are controlled by this spray if the infestations are not very severe.

Reference.—Calif. Agr. Exp. Sta. Bull. 223, 1911.

FIG. 442.—The black scale, *Saissetia oleæ* Bernard, on twig, about twice natural size. (*From E. O. Essig, University of California.*)

RED SPIDERS

Importance and Type of Injury.—Infested foliage shows many pale spots, where the mites have sucked out the green part of the leaf. The leaves are webbed on the undersides and those heavily infested turn yellow and drop. The infested fruit has a grayish or silvery appearance on the skin which decreases its market value. The loss of foliage also frequently causes the fruit to drop.

Plants Attacked.—Many different kinds of plants, both outdoors and in greenhouses, are attacked by mites of closely related species.

Distribution.—World-wide.

Life History, Appearance, and Habits.—All stages of the mites may be found on infested trees at all seasons, but they are most abundant during

the summer. The adults of these eight-legged mites are about $\frac{1}{50}$ to $\frac{1}{60}$ inch in length (see Figs. 294, 483). The body of the citrus red spider[1] is reddish in color, and the common red spider[2] is reddish yellow to grayish green. The former feeds on all parts of the leaves, the latter mainly on the undersides. The eggs are deposited on the leaves, and the young closely resemble the adults in habits and appearance, except that they have only six legs in the first instar. The citrus red spider completes a generation in about 40 days, the common red spider in about 2 weeks (see also pp. 554 and 712).

Control Measures.—Spraying with commercial lime-sulfur at 1 gallon to 50 gallons of water, or the combined oil and lime-sulfur sprays used as for the black scale, will control these pests. Sprays give the best results when applied in the spring or early summer. Dusting with finely ground sulfur, mixed with lime at the rate of 9 parts of sulfur to 1 of hydrated lime, also will control these mites. When the nights are cool and dewy, the dust should be applied during bright days with temperatures of 75 to 100° F.

Reference: Jour. Agr. Research, Vol. 36, No. 2, 1928.

Thrips

Importance and Type of Injury.—Thrips injure the citrus fruits by attacking the flowers and buds, causing them to fall. The growth of the young trees is often retarded and new growth distorted. The fruit also is attacked, and is reduced in size, and the skin is scarred, lowering the market value (Fig. 443).

Plants Attacked.—All citrus, many deciduous, fruits, and many other plants.

Distribution.—Thrips are world wide in their distribution. The citrus thrips[3] is the species causing the greatest amount of injury in California; it does not occur in Florida. The flower thrips[4] is most important in Florida. The damage by thrips is most severe in western citrus-growing regions.

Life History, Appearance, and Habits.—The winter is passed mainly as adults, and in the egg stage on the stems and leaves of the infested trees. The young thrips are yellowish, very small, slender, active creatures. They feed by rasping the plant surface, and sucking the sap that flows from these injured spots. They reach maturity in from 5 to 14 days, and at this time are about $\frac{1}{40}$ inch long, orange-yellow, with very narrow fringed wings. There are six or more generations in a season.

[1] *Paratetranychus citri* MacGregor, order Acarina, Family Tetranychidæ.

[2] *Tetranychus telarius* (Linné), Order Acarina, Family Tetranychidæ.

[3] *Scirtothrips citri* (Moulton), Order Thysanoptera, Family Thripidæ.

[4] *Frankliniella tritici* (Fitch), Order Thysanoptera, Family Thripidæ.

Control Measures.—Spraying with a combination of lime-sulfur and nicotine sulfate has proved most effective in the control of this pest. The formula most used is the following:

FIG. 443.—Oranges injured by thrips, *Scirtothrips citri* (Moulton), showing characteristic rings. (*From Essig, "Insects of Western North America," after Quayle. Copyright, 1926, by the Macmillan Company.*)

Commercial lime-sulfur	2⅔ quarts
40 per cent nicotine sulfate	½ pint
Water	50 gallons

The spray should be applied when about four-fifths of the petals have fallen; and two additional sprays should be given at intervals of 10 days. In California, the following spray is recommended:

Distillate emulsion	6 gallons
40 per cent nicotine sulfate	1½ pints
Water to make	200 gallons

Mealy Bugs[1]

Importance and Type of Injury.—Citrus trees infested with mealy bugs will have masses of white, cottony-appearing insects clustered on the leaves and twigs and at the angles where fruits touch (Fig. 444). Infested fruit is generally coated with a very sticky honeydew, which makes washing of the fruit necessary. The insects sometimes become sufficiently abundant to kill the trees.

Plants Attacked.—All citrus and many ornamental and greenhouse plants.

Distribution.—World wide. In this country, the insects are more destructive in California, although they are found in the other citrus-growing states.

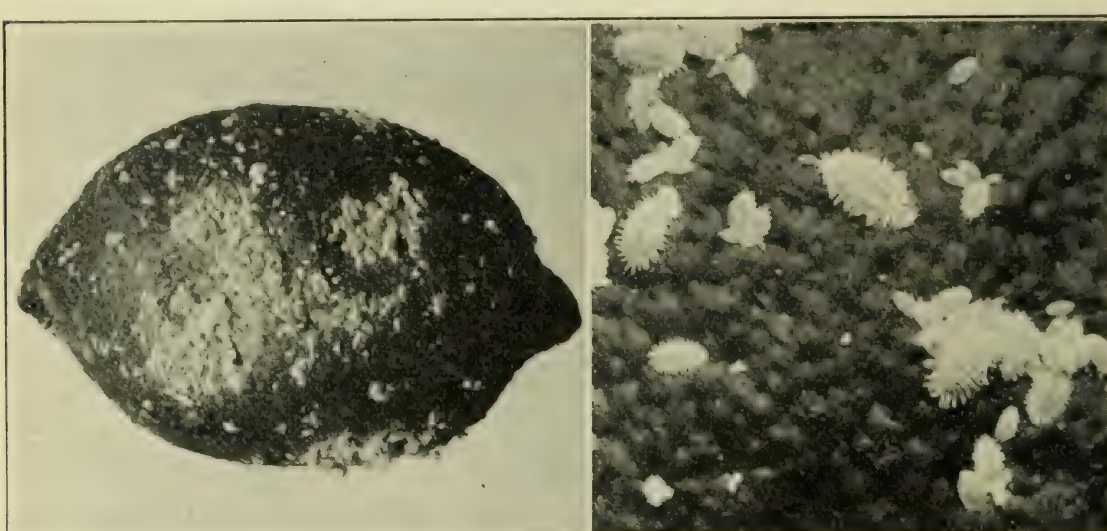


Fig. 444.—Citrus mealy bugs; at left, an infested lemon, slightly reduced; at right, adult females and nymphs of various sizes on fruit of orange, about twice natural size. (*From E. O. Essig, University of California.*)

Life History, Appearance, and Habits.—The insects can be found in all stages of development throughout the year. The mature females, which are about $\frac{1}{4}$ to $\frac{1}{3}$ inch long (Fig. 444), deposit from 300 to 400 eggs in a cottony mass of wax secreted from their bodies. The eggs hatch in from 8 to 20 days, and the young mealy bugs feed by sucking the sap or juices from the leaves or fruit. They move about but little, and require from 1 to 4 months to complete their growth. The adult males have two wings, the females are wingless throughout life. There are generally three or four generations a year.

Control Measures.—Emulsions made with refined oils, "summer oil emulsions," and crude-carbolic-acid emulsions are effective in the control of these insects. Clear water, if applied with considerable force, will

[1] *Pseudococcus citri* Risso, *Pseudococcus longispinus* Targioni, *Pseudococcus gahani* Green, and other species, Order Homoptera, Family Coccidæ.

control the pests. Fumigation is of little value. They are preyed upon by a number of natural enemies that tend to hold them in check.

Reference.—U. S. Dept. Agr. Farmers' Bull. 1309, 1923.

WHITEFLIES

Appearance and Type of Injury.—Infested trees have a blackened appearance due to a sooty mold which grows in the honeydew given off by the whitefly nymphs. This sweetish, sticky, honeydew is discharged in large quantities from the alimentary tract. Trees are stunted, through loss of sap, and the fruit is undersized and of poor color.

Distribution.—Whiteflies are widely distributed throughout the world. They are serious pests of citrus in Florida and the Gulf States, but are as yet, of little importance in California. The common citrus whitefly[1]

FIG. 445.—Citrus whitefly, *Dialeurodes citri* (Ashmead); adults and eggs on leaf, slightly enlarged. (*From Florida Agr. Exp. Sta. Bull.* 183.)

(Fig. 445) is the only one found in California. The cloudy-winged whitefly[2] and the woolly whitefly[3] are also serious pests in Florida. The spiny citrus whitefly,[4] which seems to be the most destructive of the whiteflies on citrus has not yet been found in the United States, but occurs in Jamaica, Cuba and the Bahamas.

Food Plants.—All species of citrus and many other plants. In Florida these insects breed in large numbers on Chinaberry.

Life History, Appearance, and Habits.—The life histories of all species of whiteflies which are of importance on citrus are very much alike. All stages of the insects may be found throughout the year, but little breeding takes place during cold periods. The oval eggs, less than $\frac{1}{100}$ inch in length, are attached to the under sides of the leaves by a short stalk. They hatch in from 4 to 8 days into active, pale-yellow, flattened, six-legged "crawlers," or nymphs. They move about for a short time, mainly on the lower sides of the leaves, as they avoid strong light. These crawlers soon insert their beaks into the leaves and begin sucking the

[1] *Dialeurodes citri* (Ashmead), Order Homoptera, Family Aleyrodidæ.

[2] *Dialeurodes citrifolii* (Morgan).

[3] *Aleurothrixus howardi* (Quaintance).

[4] *Aleurocanthus woglumi* Ashby (see *U. S. Dept. Agr. Dept. Bull.* 885, 1920).

sap. They soon molt, losing their legs in the process, and then have the appearance of very minute, flattened, oval bodies, attached to the undersides of the leaves by their sucking beaks (see Fig. 481). After two more molts, the adults (Fig. 445) emerge. They are small, four-winged insects about $1/16$ inch long. They have a white appearance due to the fine white powder which completely covers the wings and body. In Florida there are mainly three generations a year of the common citrus whitefly.

Control.—Spraying with oil emulsions as recommended for the purple scale has given the best control. Sprays should be applied according to conditions in the orchard. At least two sprays a year, applied in May and September, should be used in badly infested orchards. Keeping down water sprouts is of some value in controlling this insect. Certain fungi that grow on the bodies of the whiteflies are important natural enemies of these insects in Florida, but are of no importance in control in California. In Florida they generally control the insects during the summer rainy season.

Rust Mite[1]

Importance and Type of Injury.—The skin of infested oranges becomes brown or russeted, that of lemons silvered, and of grapefruits chamois-colored. The fruit does not grow rapidly, and is generally undersized at picking time. The quality of the fruit is not injured. The mites cause also russet spots on the leaves, giving them a silvery appearance; but this injury is generally slight.

Plants Attacked.—Oranges, lemons, grapefruit, and possibly some other citrus fruits.

Distribution. General in Florida, but limited to San Diego County in California.

Life History, Appearance, and Habits.—All stages of this mite may be found on the trees during the winter. The life history is much the same as that of the red-spider mites. The full-grown mites are only about $1/200$ inch in length, and barely visible to the unaided eye. They are yellow in color, with the body broadest at the head end and tapering towards the tail. These mites have only four short, weak legs, in both young and adult stages. There are many generations a year, as a complete generation may be produced in a period of 2 weeks, under the most favorable conditions.

Control Measures.—These mites may be controlled by the same measures given for red spiders.

[1] *Eriophyes oleivorus* Ashmead, Order Acarina, Family Eriophyidæ.

CHAPTER XIX

INSECTS ATTACKING SHADE TREES AND SHRUBS

Nearly all of our forest trees, shade trees, and shrubs are attacked by a large number of insects. No attempt is made in this book to treat all of the insects of forest trees. More than a thousand different species are known to feed upon the oaks, and correspondingly large numbers attack various other shade trees. A few shade trees are relatively free from injury. Shrubs are subject to attack by scale insects, especially the oyster-shell scale and San José scale. Dogwood, or *Cornus*, roses, and lilac are probably most subject to insect injury.

Where an especially destructive insect pest is well established, one should avoid planting trees or shrubs particularly likely to be attacked by this pest. In most cases, such trees or shrubs can be grown if frequently sprayed, but other species which are not subject to attack by the same insect, and which are nearly as attractive in appearance, could well be substituted. As an example, one should never plant white, green, black, or red ash in any of the cities of central Indiana, Illinois, Ohio, and neighboring states, as such trees are certain to be infested with the oyster-shell scale. The blue ash, sycamore, various maples, and many other trees can be planted in these localities, and will never be injured in the least by this scale.

The following table shows the relative resistance to insect attack of the different varieties of shade trees commonly grown in the latitude of central Ohio, and Illinois. The figure 6 has been placed opposite trees which are practically immune from insect injury; 5 indicates some damage; trees having one somewhat serious enemy are rated at 4; and those having at least one notorious insect pest at 3. Greater likelihood of injuries is indicated by 2, and still more by 1. The species of trees are arranged according to the comparative injury by insects.

TABLE XV.—SHOWING THE RELATIVE LIKELIHOOD OF INJURY TO TREES BY INSECT PESTS. TREES HAVING THE HIGHER NUMBERS SHOULD BE GIVEN PREFERENCE FOR PLANTING

Sweet gum	6	European linden	3
Tree of Heaven	6	American linden	3
Ginkgo	5	Horse chestnut	3
Red oak	5	Buckeye	3
Scarlet oak	5	American elm	3
Oriental plane	5	Hackberry	3
American plane	5	Water or red elm	3
Tulip, or tulip poplar	5	Soft or silver maple	2
Sycamore	5	European elm	2
Sugar maple	5	Scotch elm	2
Norway maple	5	Cottonwood	1
White oak	5	Carolina poplar	1
Burr oak	5	Lombardy poplar	1
Red maple	4	Balm of gilead	1
Honey locust	4	Black locust	1
Spruces	4	Box elder	1
Blue ash	4	American mountain ash	1
European mountain ash	4	Green ash	1
White pine	3	Black ash	1
Catalpa	3	White ash	1

This table follows a plan originated by Dr. E. P. Felt, State Entomologist of New York.

General References.—N. Y. State Museum, Mem. 8, Vols. 1 and 2, 1905; *Ohio Agr. Exp. Sta. Bull.* 332, 1918; *U. S. Dept. Agr. Farmers' Bull.* 1169, 1921.

FIELD KEY FOR THE DETERMINATION OF INSECTS INJURING SHADE TREES AND SHRUBS

A. Borers working in the trunks and branches:

1. Shallow mines in the bark and sapwood of the trunk and larger branches of shade trees, these mines generally occurring on the south and southwest sides of the trees. Grayish-white grubs, with a pronounced flattened enlargement of the body just back of the head, working in these burrows. Adults are flattened beetles with the body tapering back from the shoulders, the antennæ short, and their backs often irregularly roughened and metallic-colored. *Flat-headed borers or metallic wood borers,* page 664.

   (*a*) Birch trees with the leaves on the upper branches dying. Brown spots on the bark, and the inner bark of branches and trunk with many zigzag, sawdust-filled burrows running through it. White slender grubs, up to 1 inch in length, in these burrows. Entire trees dying after 1 or 2 seasons. *Bronze birch borer,* page 664.

2. Injury similar to *A*, 1, but mines more often extend through the solid wood of the tree, and the enlargment of the front end of the body is not flattened. Adults are generally more or less cylindrical beetles, with very long antennæ, and often beautifully colored. *Long-horned borers or round-headed borers,* page 665.

   (*a*) Large amounts of excelsior-like sawdust accumulating about the base of poplar, particularly Carolina poplars, aspen, and cottonwood. Ragged, usually dark-colored holes in the trunk and branches, from which dark-

colored sap is seeping and coarse sawdust is being forced out. Branches breaking, disclosing large burrows running through the wood, and greatly weakening the structure. Injury most severe on Carolina poplar, Lombardy poplar, and cottonwood. *Poplar borer*, page 666.

(*b*) Black locust trees with swollen areas on the trunk and larger branches, the bark on these areas often cracking open, or trees breaking over at the point of injury. Wood of the trees honeycombed with burrows of rather larger borers. *Locust borer*, page 667.

(*c*) Elms in a weakened, sickly condition with areas of the bark along the trunk becoming loose and easily detached from the tree. Such bark containing numerous burrows filled with brown sawdust. Yellowish-white grubs, up to a little over 1 inch in length, will be found working in these burrows. Injury occurring only on weakened or sickly trees. *Elm borer*, page 669.

3. Terminals, or leaders, of pines or spruce turn brown and die, from midsummer on, on account of the work of fat, white, legless grubs that tunnel through the wood and make "shot holes" through the bark of the twigs. Eggs laid by a reddish-brown snout beetle, about ⅓ inch long, irregularly blotched with white on the back. *White pine weevil, Pissodes strobi* (Peck) (see *N. Y. State Mus. Bull.* 175, 1915).

4. Branches and limbs of willows or poplars in northeastern United States are bored with tunnels, deformed with knotty swellings, and splitting and breaking, with sawdust and sap oozing at points of attack. Fat, white, legless grubs, ½ inch long or less, may be found tunneling in the trees from fall to midsummer. Eggs laid by blackish, chunky, snout beetles, about ⅓ inch long, with the rear third of the wing covers, the sides of the thorax, and parts of the legs pink. *Mottled poplar and willow borer, Cryptorhynchus lapathi* Linné.

5. Fine sawdust deposited in small amounts over the trunk and branches of deciduous trees. Small, round holes in the bark a little larger than a pinhead. Very small, blunt-headed, black beetles crawling over the bark or boring through the bark. Numerous galleries in the inner bark and outer sapwood, branching out from a short parent gallery. *Fruit-tree bark beetle*, page 530; *Hickory bark beetle*, page 670; *peach-tree bark beetle*, page 602; and others.

6. Swarms of very small, chunky, cylindrical, brown or black beetles, usually ⅛ to ¼ inch long, attack the trunks of various conifers or evergreen trees, eating many holes into the bark and making galleries in the inner bark and outer sapwood. Small white grubs make similar tunnels radiating from the parent gallery. Sawdust sifts down, and pitch or resin accumulates, at the entrance holes. Affected trees show reddish tops and soon die. *Bark beetles*, *Dendroctonus* spp. and others.

7. Large dark-colored burrows in the wood of locust, willow, chestnut, maple, and some other shade trees, but particularly abundant in black and red oaks. Dark-colored sap oozing from such burrows, and discoloring the bark for some distance below the burrow. Large, pinkish, brown-headed borers, up to 3 inches in length, and with well-developed prolegs, working in these burrows. *Carpenter worm*, page 671.

8. Shade trees along the eastern coast of the United States, especially elm and maple, with many dead branches in the tops of the trees, or with small branches broken over and hanging partly severed. Numerous holes along the infested branches from which sawdust is being forced out. Whitish, brown-spotted caterpillars, up to 3 inches long, in these burrows. *Leopard moth*, page 672.

9. The canes of lilacs dying, or breaking over. Slightly enlarged, swollen areas on the canes, just above the surface of the ground. Bark cracked from infested canes, showing the presence of numerous burrows through the wood. *Lilac borer*, page 673.

B. Motionless scale insects on twigs, trunks, or leaves:

1. The bark of shade trees, particularly elm and willow, with small, grayish-white, flat scales, often nearly covering the bark. From September to late spring, minute purplish eggs to the number of 50 or more, will be found under each of these scales. ***Scurfy scales***, page 675.

2. Surface of the bark of ash, poplar, and many other shade trees, covered with brownish-gray scales, which, upon close examination, will be found to resemble the half of a minute oyster shell. During the winter months, numerous pearly-white, very small eggs to the number of 75 to 100 will be found packed beneath the larger of these scales. *Oyster-shell scale*, page 675.

3. Whitish, cottony-appearing masses of wax, nearly ⅓ inch across, on the undersides of the branches of maple, linden, and other shade trees. Such masses most conspicuous during June and July. Small, flat, brownish-appearing scales, adhering tightly to the bark of shade trees during the winter months. *Cottony maple scale*, page 676.

4. Plump, rounded, reddish-brown scales, about ⅛ inch across, sharply convex and oval in outline, clustered on the twigs and branches of various shade trees during the winter months. Scales often so thick as completely to cover the bark. *Terrapin scale*, page 603.

5. Small whitish scales on the needles or leaves of pine, spruce, hemlock, and various other evergreens. Often present in such numbers as to give the needles a grayish appearance. Very small, purplish eggs beneath these scales during the winter months. *Pine leaf scale*, page 678.

C. Soft-bodied, more or less active, sap-sucking insects, on the leaves or trunks:

1. Leaves of elm with raised, much wrinkled, greenish, or pinkish galls on the upper surface. Such galls when broken open, are packed almost solid with greenish or brownish aphids. Small slits on the undersides of the leaves below the galls. *Cockscomb elm gall*, page 678.

2. Leaves of elm curled and bunched together in the spring, but no galls formed upon them. Numerous brownish aphids, with a purplish woolly-like wax covering their bodies, feeding within the curled leaves. Copious discharge of honeydew from such leaves. *Woolly apple aphid*, page 550.

3. The trunks and under sides of the branches of pines and balsam become covered with white, cottony flecks. The flocculent tufts of wax cover dark-brown aphids, that suck the sap and cause a sickly condition of the trees. *Pine-bark aphid*, *Chermes pinicorticis* Fitch.

4. Large numbers of bright-red bugs, ½ inch or less in length, the larger ones with dark wings bordered with red and with 3 red lines on the thorax, suck sap from leaves and new growth of box elder or ash. In the fall the bugs cluster in masses on the trunks, or wander in great numbers up and down the tree trunks or crawl over walls and porches and enter houses. *Box-elder bug*, *Leptocoris trivittatus*, Say (Fig. 118).

D. Leaf-eating insects:

1. Yellow-and-black beetles and grubs, about ¼ inch long, eating out the green parts of elm leaves. Large numbers of grubs collect on the bark about the base of the trunk or on the ground nearby. *Elm leaf beetle*, page 680.

2. Leaves of willows, poplars, and cottonwood partly or completely eaten. Convex, oval, yellow or reddish beetles, spotted or striped with black, about ¼ to ½ inch long, feed, along with their soft-bodied, more elongate, blackish young or larvæ, on underside of leaves. *Poplar and willow leaf beetles*, *Lina scripta* Fabricius, *Lina lapponica* Linné, *Lina tremulæ* Fabricius, and others.

3. Ends of branches, or sometimes entire branches, enclosed in a rather flimsy web, containing yellowish-black, spotted, hairy caterpillars, up to a little over 1 inch

in length. Webs usually containing many black pellets of excreta of these caterpillars. Webs most abundant during late summer and early fall. *Fall webworm*, page 564.

4. Trunk and branches of trees during winter months with dark-gray cocoons on the bark, cocoons often having masses of frothy-white eggs attached to them. Leaves of trees skeletonized, or stripped by yellowish caterpillars with two long tufts of dark hairs protruding from near the head, and one tuft from near the tail. *White-marked tussock moth*, page 687.

5. Shade trees, particularly evergreens, stripped of their leaves by brownish, rather fat-bodied worms, which live within tough silken bags. Bags up to 2 inches in length hanging in large numbers from the leaves and twigs of infested trees. Bags remaining on the trees during the winter months. *Bagworm*, page 681.

6. Catalpa trees completely stripped of their leaves by dark-colored caterpillars marked with varying amounts of green and yellow. Caterpillars up to 3 inches in length, with a curved black horn projecting from the last segment of their bodies. *Catalpa sphinx*, page 683.

7. Large colonies of black caterpillars stripping the leaves from hickory, walnut, and related trees. All foliage completely stripped from single branches. Caterpillars coming down the trunks of the trees in large numbers, and hanging in masses on the trunks while shedding their skins. *Walnut caterpillar*, page 685.

8. Buff-colored masses of eggs, up to 1 inch across, covered with felt-like hairs, on the trunks of shade trees and surrounding objects during the winter months. Large, dark gray, somewhat flattened caterpillars with pairs of red and blue spots down the back strip the leaves from trees during June and early July. *Gypsy moth*, page 690.

9. During the winter season several leaves tightly webbed together and firmly attached to a twig near the tip of the branch, enclose 25 to several hundred small, dark-brown, very hairy caterpillars, about ¼ inch long. If the caterpillars or their hairs come in contact with the skin, a distinct burning or itching results, which may persist for several days. White moths, with brown abdomens, flying in great numbers at night during July and strongly attracted to lights. *Brown-tail moth*, page 692.

10. Poplar and willow leaves eaten off during midsummer by rather large, black-bodied caterpillars. When full-grown these caterpillars are about 2 inches long, with irregular whitish colorings on the sides of the back and a nearly square white patch of hairs on the middle of the back of each segment. The adult insect is a white moth with a wing spread of nearly 2 inches. *Satin moth, Stilpmotia salicis* Linné (see *U. S. Dept. Agr. Dept. Bull.* 1469, 1927).

11. Smooth, greenish or brownish measuring worms or looping caterpillars, which lack prolegs near the middle of the body, eat foliage of elm, hackberry, oak and other deciduous trees, dropping on silk threads when disturbed. *Cankerworms*, pages 555 and 557.

12. Spruce or balsam trees appearing as though scorched by fire and slowly dying. Thick, dark-brown caterpillars, ¾ inch or less in length, covered with pale-yellow warts, eat off the needles and spin silken threads over the twigs in early spring. *Spruce budworm, Harmologa fumiferana* Clemens.

13. Greenish, yellowish, whitish or bluish, worms, 1 inch or less in length, often spotted or striped with black or yellow, with dark heads and 9 to 11 pairs of legs and prolegs, defoliate elm, birch, poplar, willow, pine, larch, spruce, balsam, or other trees during the summer. Worms usually hold their bodies or tails coiled or curved over edge of leaves. *Sawflies* (Order Hymenoptera, Family Tenthredinidae).

E. Twigs girdled, severed or splintered so that they die and hang broken over or fall to the ground:

1. Many twigs, ⅛ to ¾ inch in diameter and several feet long, neatly cut off and lying on the ground beneath hickory, persimmon, oak, poplar, sour gum, honey locust, and other deciduous shade, fruit, and nut trees. Severed end of twig is convex and

no borers in the new fallen twigs. Grayish, cylindrical, hard-shelled beetles, nearly 1 inch long, with antennæ longer than the body, girdle the twigs by cutting round and round them from the bark inward. *Twig girdler, Oncideres cingulata* Say, and other species (Fig. 5, *D*).

2. Twigs severed as in *E*, 1, from oak, maple, hickory, chestnut, locust, and other shade and fruit trees. Severed end of twig is concave and with a central burrow leading from it up the twig, which is plugged with shavings and contains a white, cylindrical, conspicuously segmented grub, which cut off the twig from the inside. *Maple and oak twig pruner, Ellaphidion villosum* Fabricius.

3. Tips of small branches breaking off or hanging with dead leaves during the early summer, wood split at point of break, with tufts of splinters sticking up at short intervals along the twig. *Periodical cicada*, page 533.

Flat-headed Borers[1]

There are several species of borers belonging to this group, which are very common, attacking practically all kinds of trees. The typical injury consists of rather shallow galleries in the bark, usually on the south or southwest side of the trees. Areas of the bark become entirely undermined. In these galleries are to be found medium to rather large, yellowish-white grubs, with a pronounced flattened enlargement of the body (thorax) just back of the head. A typical life history of these insects is given under Apple Insects, page 526.

The control of the flat-headed borers on shade trees is the same as on apple. Trees that have been taken from the nursery and are set in situations exposed to the sun, should be protected at least during the first season by having a board driven in the ground, or attached to a stake, 3 or 4 inches from the tree on the south and southwest sides, to shade the tree from the direct rays of the sun. The ways recommended to prevent the beetles' laying their eggs on apple trees may be used on shade trees (see p. 527).

References.—Jour. Econ. Entomol., Vol. 11, p. 334, 1918; *N. Y. State Museum, Mem.* 8, Vol. 2, p. 653–658, 1905.

Bronze Birch Borer[2]

Importance and Type of Injury.—This flat-headed borer is a very serious pest of birches, and is capable of destroying nearly every white or paper birch in a locality where it is allowed to increase unchecked. Infestation is first indicated by a browning of the tips of the upper branches, followed by the death of the entire tree. Infested branches will often appear somewhat swollen, with ridges around the smaller ones. Small, slightly oval holes, about ⅛ inch in diameter, will be found in the bark. An examination of the inner bark will show numerous burrows, tightly

[1] *Chrysobothris femorata* (Olivier) and many other species, Order Coleoptera, Family Buprestidæ.

[2] *Agrilus anxius* Gory, Order Coleoptera, Family Buprestidæ.

packed with sawdust, running in every direction and containing slender white grubs about 3/4 inch long, with a slight enlargement of the body just back of the head.

Trees Attacked.—The white or paper birches are most severely injured. The insect has been found also in several other species of birch.

Distribution.—It is a native American insect, generally distributed throughout the northern United States and southern Canada, westward to Idaho.

Life History, Appearance, and Habits.—The winter is passed as full-grown larvæ in cells just within the sapwood. These larvæ are from 1/2 to 3/5 inch in length, white in color, very slender, with a slight enlargement of the thorax, and with two rather slender, brownish projections from the last segment of the body. In the spring the larvæ pupate within their cells in the wood and emerge during May, June, and July, as greenish-bronze beetles about 1/2 inch long, with rather blunt heads and slender, pointed bodies (Fig. 446). The female beetles deposit their eggs in cracks in the bark. These soon hatch into tiny borers that work their way into the inner bark, becoming full-grown by fall, and excavating cells in the sapwood. The burrows of the insect are very crooked, and cross and recross, often completely cutting off the circulation of the sap. There is but one generation of the insect each year.

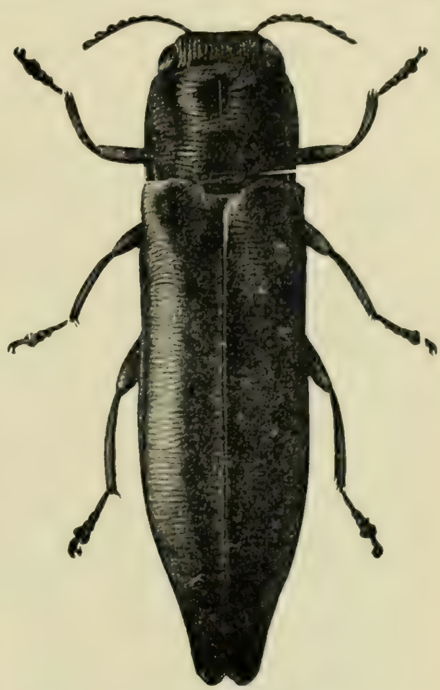


Fig. 446.—Bronze birch borer, *Agrilus anxius* Gory, adult, about six times natural size. (*From Ill. State Nat. Hist. Sur.*)

Control Measures.—No sprays can be applied for the control of this insect. The only effective method of checking their increase is to cut out and carefully burn, during the winter, all infested parts of trees. If this is done each year, infestations may be held down to a point where little damage from the insect will result. All infested material should be cut out not later than the first of April.

Long-horned Borers[1]

The family of beetles known as long-horned or round-headed borers[1] are even more numerous and destructive than the flat-headed borers. The larvæ, or grubs, work beneath the bark and also tunnel through the heartwood, often riddling the trunks of trees with holes that are as large as a pencil to much larger. These grubs (Fig. 451) also have an enlarge-

[1] Order Coleoptera, Family Cerambycidæ.

ment of the body behind the head, but it is not so much flattened as in the flat-headed borers. A typical life history is given under Apple Insects, page 527.

Besides the locust borer, elm borer, and poplar borer, discussed below, there are a number of other species which attack various species of shade trees. A few of these attack the perfectly healthy trees, while others are attracted only to trees in a weakened or sickly condition. The only practical method of control known is to use carbon bisulfide in the burrows as described for the poplar borer, or to cut and burn the badly infested trees during the winter, when the insects are all within the trunk or bark in the larval stage. Linden, maple, oak, hickory, and willow are particularly subject to attack by some of these borers.

Poplar Borer[1]

Importance and Type of Injury.—Damage by this insect frequently makes it impossible to grow certain species of poplars in some localities. It is the most destructive borer attacking poplar trees. Infested trees have many large burrows, with openings through the bark, on the trunk and large branches. The entrance to these burrows is usually packed with coarse, excelsior-like wood fibers. An accumulation of these fibers or sawdust-like material will often be noticed around the base of the trunk. There is generally a discharge of sap from the opening to the burrow, which wets and discolors the bark of the tree for some distance below it. The wood of the tree is weakened, so that the branches or the main trunk break during periods of high wind.

Fig. 447.—Poplar Borer, *Saperda calcarata* Say. Adult female, slightly enlarged. (*From U. S. D. A. Farmers' Bull.* 1154.)

Trees Attacked.—Carolina poplar, cottonwood, and Lombardy poplar, are the most seriously injured. It has also been found in some other species of poplars and in willow.

Distribution.—This is a native insect, distributed generally in the United States and Canada.

Life History, Appearance, and Habits.—The winter is passed as a yellowish, rather round-bodied grub, from 1 to nearly 1½ inches in length. These grubs will be found in large burrows in the wood of the tree. They start feeding as soon as the weather becomes warm in the spring, and continue throughout the season. They bore through the wood of the tree, cutting out large galleries, sometimes as much as an inch in diameter. Some of the borers become full grown by late spring. They are then about 2 inches long. They pupate in cells in the wood, and emerge as

[1] *Saperda calcarata* Say, Order Coleoptera, Family Cerambycidæ.

beetles from July to September. The adult beetles (Fig. 447) are from 1 to $1\frac{1}{2}$ inches in length, with long antennæ slightly darker than the body. The beetle is of a general light-gray color, with irregular, somewhat elongated, small yellowish spots, and the whole body is sprinkled with minute black dots. The female deposits her eggs in cracks in the bark. These eggs hatch in a few days into small grubs, which feed at first in the outer bark, but work their way rather quickly into the inner bark and sapwood. At least 2 years are required for the grubs to complete their growth. Under unfavorable conditions this period may extend over 3 years.

Control Measures.—Trees that are especially valued for shade, may be freed of most of the borers by carefully going over the tree and injecting a small amount of carbon bisulfide into all openings leading into the burrows. A machine oilcan is best suited for injecting the carbon bisulfide. The hole should be closed immediately after injecting the chemical, using a wad of wet clay or putty for this purpose. An examination of the infested trees two or three times from the first of June to the first of October, treating each time all burrows from which fresh sawdust is being forced out, will kill practically all insects in the trees. Experiments have shown that all grubs within 6 to 10 inches of the point where the carbon bisulfide is injected will be killed. Badly infested trees should be cut during the winter or early spring, and all of the large branches and trunk burned to prevent emergence of the adult beetles. Cutting and piling the wood will not be effective, as the larger grubs will complete their growth, and emerge as beetles to reinfest neighboring trees.

References.—Ohio Agr. Exp. Sta. Bull. 332, p. 319, 1918; *U. S. Dept. Agr. Farmers' Bull.* 1154, 1920; *N. Y. State Museum, Mem.* 8, Vol. 1, p. 98, 1905.

Locust Borer[1]

Importance and Type of Injury.—Black-locust trees have swollen areas on the trunk, often with the bark cracked open, exposing burrows in the tree sometimes ½ inch in diameter. The wood is nearly always discolored and blackened in and around these burrows. Young locust trees break over during the late summer, by reason of numerous burrows through the tree which have weakened it (Fig. 449). This insect is so numerous throughout most of the eastern United States as to prevent profitable growing of black locust. If this insect could be controlled, the black locust would be one of our most valuable farm wood-lot trees.

Trees Attacked.—Black locust.

Distribution.—The locust borer is found throughout the United States east of the Rocky Mountains, and in southern Canada.

[1] *Cyllene robiniæ* Förster, Order Coleoptera, Family Cerambycidæ.

Life History, Appearance, and Habits.—The winter is always passed as a very small grub or larva within the inner bark or barely to the sapwood of the infested trees. Early in the spring these grubs begin feeding, and burrow their way into the wood of the tree, going through both the sapwood and the heartwood. These burrows are very irregular in direction, and are frequently so numerous as to cause the death of the tree. The tree may break over during periods of high winds. The larvæ become full-grown about midsummer. At this time, they are

FIG. 448.—The locust borer, *Cyllene robiniæ* Förster; adult female about twice natural size. (*From Ill. State Nat. Hist. Sur.*)

FIG. 449.—Young locust tree broken at point of injury by larvæ of the locust borer. (*From Ohio Agr. Exp. Sta. Bull.* 332.)

¾ to nearly 1 inch in length, tapering from the thorax backward, giving them a club-shaped appearance. These larvæ excavate cells in the wood, and here change to the pupal stage. The adult beetles begin coming out about the first of September in the latitude of Illinois. They are of a general black color, marked with bright yellow crosslines (Fig. 448). The legs and antennæ are dull red, the underside of the body jet black. They are extremely active, flying readily from tree to tree and scuttling about over the bark. They feed on the flowers of goldenrod and a few other allied plants. Feeding in the adult stage is not necessary, as the females will lay their eggs without having fed. The elongate white eggs are tucked into crevices and cracks in the bark. These hatch in about 2 weeks, and the young work their way through the

outer bark and into the inner bark, or just to the surface of the sapwood, before the approach of cold weather. There is one generation each year.

Control Measures.—Trees grown in heavy stands are somewhat less infested than those grown in the open. However, even the trees growing in dense shade, are not entirely free from injury. A mixture of tree tanglefoot 9 parts and 50 per cent sodium arsenite solution, 1 part, applied as a band around the trunk of the tree, kills all beetles that come in contact with it.

References.—*U. S. Dept. Agr. Bur. Entomol. Bull.* 58, Parts I and III, 1906; *Rept. Ky. State Forester*, 1915; *Ohio Agr. Exp. Sta. Bull.* 332, 1918.

Fig. 450.—The elm borer, *Saperda tridentata* Olivier. Adult about three times natural size. (*From Ill. State Nat. Hist. Sur.*)

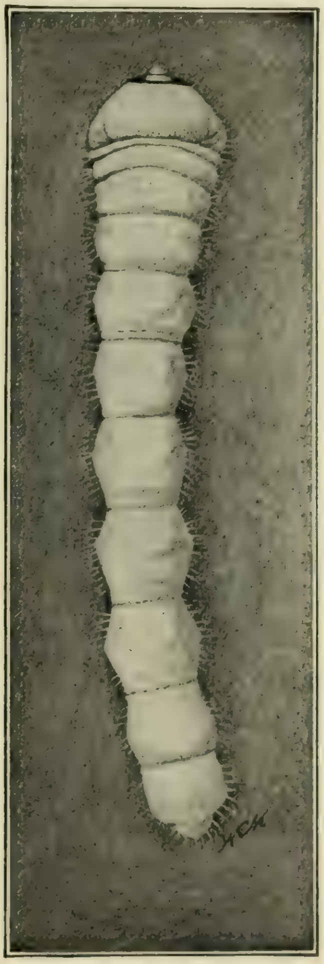


Fig. 451.—The elm borer, larva, about three times natural size. (*From Ill. State Nat. Hist. Sur.*)

Elm Borer[1]

Importance and Type of Injury.—Branches of elm dying, or entire trees with foliage undersized and of a general yellow color, is the symptom of attack by this round-headed borer. Numerous galleries run through the inner bark and sapwood. The

[1] *Saperda tridentata* Olivier, Order Coleoptera, Family Cerambycidæ.

outer bark is often darkened and loosened from the tree. These galleries are tightly packed with frass or brownish sawdust.

Trees Attacked.—White elm and slippery elm.

Distribution.—Throughout the eastern United States.

Life History, Appearance, and Habits.—The winter is passed as partly grown larvæ in the bark and sapwood of the tree. In the spring, these larvæ begin feeding on the inner bark and wood, running their irregular galleries in all directions. They become full-grown late in the spring, and change to a pupal stage in cells in the sapwood. They emerge during late spring and early summer as gray, long-horned beetles, about ½ inch in length (Fig. 450). The wing covers are bordered on the outer margin with a narrow line of red, and there are three fine extensions of this red line across each wing cover. The eggs are laid in cracks in the bark, and the grubs on hatching work their way into the inner bark and sapwood. The galleries running through the inner bark, cut off much of the sap flow. Most of the grubs (Fig. 451) are about two-thirds grown by fall. There is probably one generation of the insect each year, except in cases where conditions are unfavorable to the growth of the grubs, when they may require two seasons to complete their growth.

Control Measures.—The most effective control for this beetle, as well as for many other shade tree insects, is to keep the trees in as vigorous condition as possible. The elm borer seems to be attracted to trees which are in a sickly condition, or lacking in vigor because of insufficient plant food or moisture. Keeping the trees well supplied with water, and well fertilized, will do much to prevent injury by this insect. Sickly trees, or large branches which are dead or dying, should be cut out and burned during the winter months. Such trees or branches act as breeding places for the beetle, and as centers of infestation for all elms in the neighborhood.

FIG. 452.—Hickory bark beetle, *Scolytus quadrispinosus* Say; adult, about seven times natural size. (*From Ill. State Nat. Hist. Sur.*)

References.—*Ill. Agr. Exp. Sta. Bull.* 151, 1911; *N. Y. State Museum, Mem.* 8, p. 67, 1905.

BARK BEETLES[1]

There are a number of species of small black or brown beetles (Fig. 452) that attack the bark of shade trees, when such trees are in poor condition from lack of moisture, insufficient plant food, or other causes. They feed in the cambium, making very many fine burrows (Fig. 453) that eventually cut off the sap flow and kill the tree.

A typical life history of these beetles is given under Fruit Insects, page 602. Some species of bark beetles have more than one generation a year, but all injure trees in practically the same way. The only effective control is to keep the trees in a vigorous growing condition by supplying enough water and plant food, and to keep all dying and injured wood pruned out. Such pruning should be done during the winter or

[1] The hickory bark beetle, *Scolytus quadrispinosus* Say, and many others of the Order Coleoptera, Family Scolytidæ.

early spring months, and all such wood should be carefully burned. If allowed to remain piled up or near the trees, it may act as a breeding place for bark beetles which will infest the growing trees in the neighbor-

FIG. 453.—Work of the hickory bark beetle, *Scalytus quadrispinosus* Say, in a 12-inch hickory tree. The dead bark has been removed. Note the straight, vertical egg galleries made by the females, and, radiating from each egg gallery, the numerous mines made by the growing larvæ. (*From N. Y. State College of Forestry, Tech. Bull. No.* 17.)

hood. No effective spray is known that can be used in combating these insects.

References.—Dom. Can., Dept. Agr. Tech. Bull. 14, Parts I and II, 1917–18; *Miss. Agr. Exp. Sta. Tech. Bull.* 11, 1922; *Ore. Agr. Exp. Sta. Bulls.* 147, 1918 and 172, 1920; *U. S. Dept. Agr. Farmers' Bull.* 1188, 1921; *U. S. Dept. Agr. Bureau Entomol. Bulls.* 56, 1905; 58, 1906–09; and 83, 1909.

CARPENTER WORM[1]

Importance and Type of Injury.—This insect is very common on many shade trees, especially on oak. Infested trees have large burrows running through the wood, with occasional openings through the bark of the trunk, from which sawdust may be forced out, or from which a discharge of dark-colored sap will be oozing and discoloring the trunk. The burrows of the insect in the trunk will sometimes be as much as 1 to 1½ inches in diameter. These galleries occasionally are so numerous as to weaken

[1] *Prionoxystus robiniæ* Peck, Order Lepidoptera, Family Cossidæ.

trees, and cause them to be broken off during high winds. The injury also greatly lessens the value of lumber or posts from infested trees.

Trees Attacked.—Oaks, particularly those of the black-oak and red-oak group, maple, cottonwood, willow, and chestnut.

Distribution.—The insect is generally distributed throughout the United States and southern Canada.

Life History, Appearance, and Habits.—The winter is passed in the larval stage in the burrows in the trunk and large branches of the tree. The borers will vary in size, according to their age, from 1 inch up to 2 inches or a little over. The general color is white tinged with pink, with a very dark-brown head and numerous dark brown tubercles over the body. The insects pupate in large cells excavated in the wood of the

FIG. 454.—The carpenter worm, *Prionoxystüs robiniæ* Peck, adult female, natural size. (*From Ohio Agr. Exp. Sta. Bull.* 332.)

tree, and just before emerging the pupæ work part way out of the burrow. The adult moth on emerging generally leaves the empty pupal skin protruding from the tree. The moths are abroad at night during the summer months. In this stage, the insect is of very striking appearance (Fig. 454), having a wing expanse of as much as 3 inches, in the female. The moths are of a general gray color, mottled with lighter shadings, the hind wings being faintly tinged with yellow. In the male the hind wings have a distinct orange margin. The eggs are laid in crevices in the bark and the young borers on hatching immediately work their way into the wood of the tree. Three years are probably required for completion of the larval growth.

Control Measures.—There is no effective practical control known for combating this insect.

Reference.—Ohio Agr. Exp. Sta. Bull. 332, p. 329, 1918.

LEOPARD MOTH[1]

Importance and Type of Injury.—Branches, especially in the tops of trees, are dead and smaller branches broken over or hanging partly cut off, during the latter part of the summer. The leaves wilt suddenly on small branches. There are holes along such branches, from which damp sawdust is being pushed out (Fig. 455).

Trees Attacked.—Elms and maples are the favored food plants, but the insect attacks also many other deciduous shade trees.

[1] *Zeuzera pyrina* Linné, Order Lepidoptera, Family Cossidæ.

Distribution.—This moth is a native of Europe. It was first found in the United States in New York, in 1882. It is now well established along the Atlantic Coast from New Jersey northward to New Hampshire.

Life History, Appearance, and Habits.—The winter is passed as a partly grown larva, from 1 to $1\frac{1}{2}$ inches in length, in burrows in the heartwood of infested trees. The worms (Fig. 455) are of a pinkish-white color, with many dark-brown spots distributed over the body. In the spring the worms start feeding and boring through the wood, the smaller ones continuing to feed throughout the season, while the larger ones become full-grown in the late spring and change to a brown pupal stage within their burrows. When the moth is ready to emerge, the pupa forces itself partly out of the burrow and the skin splits down the back, permitting the adult moth to escape. Emergence takes place from June to early fall. The adults (Fig. 455) are very striking in appearance, being of a general white color, blotched and spotted with blue and black. They have a wing expanse of from 2 to 3 inches. The eggs to the number of 400 to 800 are laid in crevices of the bark. They hatch in about 10 days, and the young borers rapidly work their way into the heartwood of the branch. It requires from 2 to 3 years for the insect to complete its growth.

Fig. 455.—The leopard moth, *Zeuzera pyrina* Linné; work in small twig, and borings hanging from bark, nearly full grown larva and adult moth. One-half natural size. (*From Felt, "Manual of Tree and Shrub Insects," copyright*, 1924, *by the Macmillan Company. Reprinted by permission.*)

Control Measures.—Where this insect is abundant, it is very important that all infested branches be cut and burned during the fall and winter months. It is quite easy to detect the infested branches during the early fall months, because of the wilting of the leaves and the numerous holes along the branches from which the sawdust is being thrown out.

References.—*Conn. Agr. Exp. Sta. Bull.* 169, 1911; *N. Y. State Museum, Mem.*, 8, Vol. 1, pp. 75–79, 1905; *U. S. Dept. Agr. Farmers' Bull.* 1169, 1925.

Lilac Borer[1]

Importance and Type of Injury.—Lilac canes are dying, the base of the canes exhibiting swollen areas where the bark is cracked and broken away from the wood. There are numerous holes through the bark and wood. Canes suddenly wilt and show fine, sawdust-like borings forced out from holes in the bark. Figure 456 shows typical injury on ash.

Plants Attacked.—Lilac and ash are the two most seriously infested, although the insect is occasionally taken in some other trees.

Distribution.—Eastern United States, westward to Colorado.

Life History, Appearance, and Habits.—The winter is passed as a partly grown larva in the stems of lilac, usually near the surface of the

[1] *Podosesia syringæ* Harris, Order Lepidoptera, Family Ægeriidæ.

soil, and in infested trees. The insect starts feeding in the spring and completes its growth by early summer. At this time it is a nearly pure-white worm, about $1\frac{1}{2}$ inches long, with a brown head. It transforms in the burrow to a brown pupal stage and emerges in about 3 weeks as a clear-winged moth of a somewhat wasp-like appearance. The

FIG. 456.—Ash tree injured by lilac borer, *Podosesia syringiæ* Harris. (*From Ill. State Nat. Hist. Sur.*)

fore wings are of a general brown or chocolate color, the hind wings are clear, marked with a dark border. The body is mainly brown and the legs are marked with brown and yellow. The insect is about 1 inch in length with a wing expanse of $1\frac{1}{2}$ inches. The moths are very active fliers. The females deposit their eggs on the bark about the base of lilac canes, or on ash. The worms, hatching from them, become about half grown by cold weather. There is one generation a year.

Control Measures.—The only effective method of combating this insect is to cut out in the late summer, or early fall, all canes showing infestation. Some of the borers may be killed in their burrows in the bark, by injecting carbon bisulfide with a machine oilcan as recommended for the poplar borer.

Reference.—Twenty-sixth Rept. Ill. State Entomol., 1911.

Scurfy Scales[1]

Importance and Type of Injury.—These scales are often very injurious to smaller elm, willow, and dogwood. They are rarely a serious pest on large trees. Infested branches show small, flattened, dirty white scales about $\frac{1}{10}$ of an inch long, lying nearly flat on the bark. In the winter many, reddish-purple eggs, just discernable with the naked eye, will be found beneath these scales. On heavily infested trees, the entire bark may be coated with the grayish scales.

The life history and control for these scales is similar to that of the apple scurfy scale given on page 543.

Oyster-shell Scale[2]

Importance and Type of Injury.—Branches of trees or entire trees are dying, the bark cracking and having much the appearance of drying up on the branches. The bark is covered with small, brownish-gray scales about $\frac{1}{8}$ inch long by $\frac{1}{16}$ inch wide, usually curved and closely resembling a minature oyster shell (see Fig. 352). The bark may be completely covered with these scales.

Trees Attacked.—All species of ash, with the exception of the blue ash, poplar, dogwood, elm, soft maple, linden, horse chestnut, lilac (with the exception of the white lilac), many species of rose, and many other shade trees and shrubs. The very closely related form attacking apple is described on page 544.

Distribution.—General throughout the United States.

Life History, Appearance, and Habits.—The winter is passed in the egg stage under the female scale. These eggs are elliptical nearly white in color, and from 50 to 60 will be found under each female scale. They hatch late in the spring after the trees have come into full foliage. In the latitude of central Illinois, this is about June 1. The white, six-legged young, just discernable to the naked eye, crawl about over the tree for a few hours and then insert their beaks into the bark and begin sucking the sap. They soon molt, and the females remain in this position for the rest of their lives. They grow rather rapidly, secreting the wax which forms into the brown protective scale over their bodies. About midsummer, or a little later, the males become

[1] Order Homoptera, Family Coccidæ. The elm scurfy scale is *Chionaspis americana* Johnson; the one on dogwood is *Chionaspis corni* Cooley; and the one on willow is *Chionaspis salisis-nigræ* (Walsh).

[2] *Lepidosaphes* sp., Order Homoptera, Family Coccidæ.

full-grown and change, under their scales, to minute, yellowish-white, two-winged insects, which fly about for a short time, mate with the females, and die. After mating, the female deposits her eggs, her body gradually shrinking to the small end of the scale, where she finally dies. There is but one generation of this species of oyster-shell scale each year. Another kind of oyster-shell scale, somewhat closely resembling this one, occurs on certain species of dogwood. The dogwood form has two generations each year.

Fig. 457.—The cottony maple scale, *Pulvinaria vitis* (Linné). Brownish bodies of female scales partially covering the large white tufts of wax that enclose the eggs of the scale, in late spring. Each sac of wax may enclose more than 1,500 eggs. (*From Chambers, Wis. Dept. Agr.*)

Control Measures.—Spraying thoroughly with lime-sulfur, used at a dilution of 1 part, 33° Bé. lime-sulfur to 7 parts of water, just before the leaves come out, will clean up this scale, if the treatment is persisted in for 3 or 4 seasons. The effect of this spray is mainly from the residue remaining on the bark, which prevents the young scales, after hatching, from attaching themselves to the bark. A more effective method is to spray at the time the young scales are hatching, using a miscible oil that will not injure foliage, or a lubricating-oil emulsion (see p. 250), applied at a strength of 2 per cent oil. Very thorough applications must be made in order to hit all parts of the tree, which at this time is protected by the foliage. Recent experiments with this method have shown it to be the most effective for the control of this insect. Spraying with oils during the dormant season cannot be relied on to prevent more than 80 or 90 per cent of the eggs from hatching. The planting of resistant shade trees, such as the blue ash, hackberry, hard maples, and oaks will keep down this scale, as it does not breed on these trees.

References.—Ohio Agr. Exp. Sta. Circ. 143, 1914; *Jour. Econ. Entomol.* Vol. 13, p. 173, 1920.

Cottony Maple Scale[1]

Importance and Type of Injury.—This is one of the most destructive scales on soft maple, and also injures some other trees. Attention is usually attracted to infested trees by the cottony-appearing masses of scale along the underside of the twigs and branches during May and

[1] *Pulvinaria vitis* (Linné) Order Homoptera, Family Coccidæ.

June (Fig. 457). Branches of heavily infested trees die, and the foliage of the entire tree turns a sickly yellow. The reduction of the vigor of the tree by the scale often leads to attacks by bark beetles or other borers.

Plants Attacked.—Soft maple, linden, Norway maple, apple, pear, willow, poplar, grape, hackberry, sycamore, honey locust, beech, elm, plum, peach, gooseberry, Virginia creeper, currant, sumac, and some others.

Distribution.—The insect is distributed throughout the United States and Canada. It is most destructive in the northern part of the United States.

Life History, Appearance, and Habits.—The cottony maple scale passes the winter as a small, brown, flattened scale, a little less than 1/8 inch long, attached to the bark of twigs and small branches. These scales are all females. In the spring, as soon as the sap starts to flow, they grow very rapidly, and soon begin depositing their eggs, which are secreted in cotton-like masses of wax under the scale. This wax is secreted in such abundance that it forms a mass several times the size of the overwintering insect, and the body of the scale often becomes elevated at an angle from the twig. From 1,500 to 3,000 eggs are laid by each female. The eggs hatch during late June and July, in the latitude of central Illinois, and the young scales crawl from the twigs to the undersides of the leaves, where they suck the sap along the midrib or the veins. They become mature during August and September, mating takes place and the males die, the females crawling back to the twigs and small branches, where they pass the winter.

Control Measures.—Spraying during the early spring, just before the leaves put out on the maples, is the most effective method of controlling this scale. The best spray to use is a good oil emulsion, at the strength recommended by the manufacturer, or home-made oil emulsion (see p. 250) at a strength of 2 per cent oil. A complete clean-up may be obtained by this treatment. Summer spraying is of very little value.

References.—Twenty-sixth Rept. Ill. State Entomol., p. 62, 1911; *Ohio Agr. Exp. Sta. Bull.* 332, 1918.

Terrapin Scale[1]

Nearly hemispherical, reddish-brown scales, about 1/8 inch across and very convex in outline, cluster on the bark of twigs and branches (see Fig. 403). The scale is generally somewhat mottled and streaked with black. The bark is often entirely covered for considerable distances along the branches.

Maple and sycamore are most severely injured. It also attacks osage orange, peach, plum, pear, quince, and some other shade trees. The distribution, life history, and control of this insect are discussed on page 603.

[1] *Eulecanium nigrofasciatum* Pergande, Order Homoptera, Family Coccidæ.

Pine Leaf Scale[1]

Importance and Type of Injury.—Infested trees have the foliage somewhat yellowed, with rather elongated, whitish scales up to ⅛ inch in length, attached to the leaves. These white scales (Fig. 458) on the green leaves or needles of pine or other evergreens, often first attract notice to the presence of the insects.

Trees Attacked.—Pines, spruces, firs, and hemlocks.

Distribution.—Throughout the northern United States and southern Canada.

Life History, Appearance, and Habits.—The winter is passed in the form of very minute, purplish eggs underneath the gray parent scale. From 20 to 30 of these eggs will be found under each scale. The eggs hatch in midspring into crawling young, which move about for a short time, and then settle down and secrete a scale about their bodies. They become full-grown by late summer, and a second generation is produced from eggs laid during August. These, in turn, become full-grown, and the females deposit eggs, by fall. In the latitude of Illinois and Ohio there are two generations annually, although probably only one farther north.

Control Measures.—Spraying with dilute oil emulsion, at the time the eggs of this scale are hatching, is the most effective method of control. A good home-made oil emulsion at a strength of 2 per cent oil, will not injure the trees unless applied in large amounts or during very hot weather. If a commercial oil is used, care should be taken to secure an oil that is recommended for use on evergreens, as these trees are more susceptible to injury than deciduous trees.

Reference.—*Ohio Agr. Exp. Sta. Bull.* 332, p. 291, 1918.

Fig. 458.—The pine leaf scale, *Chionaspis pinifoliæ* Fitch. One leaf shows the small male scales and the larger female scales. The width of the scales varies to some extent with the width of the leaf. About twice natural size. (*From Ohio Agr. Exp. Sta. Bull.* 332.)

Cockscomb Elm Gall[2]

Importance and Type of Injury.—This aphid seldom causes the death of the elm trees, but often becomes annoying because of the fact that its galls make the trees unsightly. Leaves of elms infested with this aphid, have crinkled reddish galls on their upper surfaces. These galls quite closely resemble a minature rooster's comb (Fig. 459). During the early part of the growing season, the galls are green or reddish in color. During the late summer, they dry and become brown. An examination of the green galls will show that they are filled with small, rather smooth, greenish or brownish aphids. A narrow slit on the underside of the leaves, serves as an entrance to the gall, although during the early part of the season this slit is so nearly closed that the aphids cannot get through it.

Trees Attacked.—Elm, especially red elm.

Distribution.—General over the United States.

Life History, Appearance, and Habits.—The winter is passed as a dark-brown shiny egg in cracks in the bark of the elm tree. These eggs hatch in the spring when the leaves are partly grown. The aphids crawl to the leaves and begin feeding by sucking the sap. Where they start to feed, the peculiar gall formations start growing, enclos-

[1] *Chionaspis pinifoliæ* Fitch, Order Homoptera, Family Coccidæ.

[2] *Colopha ulmicola* Fitch, Order Homoptera, Family Aphididæ.

ing the aphids. The aphids remain inside these galls, giving birth to living young, so that if the gall is broken open during the summer, it will be found swarming with aphids. As the aphids feed, they give off quantities of honeydew, which drops from the galls as they begin to crack open late in the season, often nearly coating the surfaces of walks under the trees. This honeydew, attracts flies and other insects, which add to the unsightly appearance of infested trees. During the summer, the galls crack open and the aphids make their way out. Winged migrants carry the species to the roots of various grasses, where the aphids live during the summer, returning to elms in the fall.

Fig. 459.—The cockscomb elm gall, *Colopha ulmicola* Fitch. A number of galls on leaves of white elm. About natural size. (*From Washburn, "Injurious Insects and Useful Birds," courtesy J. B. Lippincott Co.*)

Control Measures.—There is no practical control measure for this insect other than cutting off the galls early in the season, as soon as they start showing on the leaves. This of course, can be done only on small trees, or those that are especially valuable.

Reference.—Ohio Agr. Exp. Sta. Bull. 332, p. 311, 1918.

Woolly Apple Aphid

This insect is described and the means of control are given under Apple Insects, page 550. It frequently becomes very abundant on elm where its feeding on the leaves in the spring causes them to curl and bunch together. No true galls are formed by this insect, so that it can be readily distinguished from the work of the cockscomb gall aphid.

Other Aphids of Shade Trees and Shrubs

Nearly all shade trees and ornamental shrubs suffer to some extent from the attacks of aphids, especially *Spiræa van Houtii*, roses of all varieties, snowball, poplar, sycamore, and maple. In general, the life history and control of these aphids is very similar to that described on pages 442 and 546.

Elm Leaf Beetle[1]

Importance and Type of Injury.—This beetle is one of the most destructive pests of the elm tree throughout the eastern United States. Infested trees have a general yellow appearance of the foliage, with many leaves skeletonized. Yellowish to dull-green beetles about ¼ inch long, with an indistinct black stripe along each side (Fig. 460, *5*, *6*), or small yellow to black larvæ (*2*, *3*) will be found feeding on the leaves, or crawling

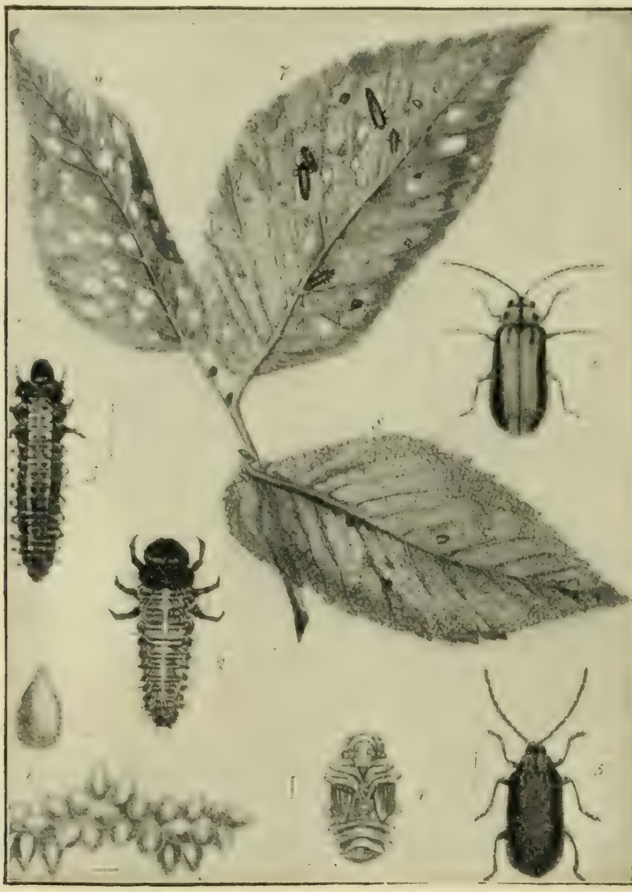


Fig. 460.—The elm leaf beetle, *Galerucella xanthomelæna* Schrank. 1, egg mass, 2, young larva, 3, full grown larva, 4, pupa, 5 and 6 adult beetles, about twice natural size; above injured leaves, reduced. (*From Felt's "Manual of Tree and Shrub Insects," copyright*, 1924, *by the Macmillan Company. Reprinted by permission.*)

about on the bark of the trunk, sometimes clustered in great numbers about the base of the trunk.

Trees Attacked.—The different species of elm, the English elm and camperdown elm being most subject to attack.

Distribution.—The elm leaf beetle is of European origin, and was probably brought into this country some time about 1850. It is now established over most of the eastern United States, and has been found as far west as Indiana and Kentucky. It has never been taken in Illinois,

[1] *Galerucella xanthomelæna* Schrank, Order Coleoptera, Family Chrysomelidæ.

but has been found in many of the west central states, and in Washington, Oregon, and California.

Life History, Appearance, and Habits.—The adult beetles go through the winter hidden away in sheltered places which will afford them some protection from the weather. They are about ¼ inch long, of a reddish-yellow color, with several black spots on the head and thorax, and somewhat indefinite black lines on the wings. The beetles fly to the elm trees shortly after they come into foliage in the spring, and deposit double rows of yellowish eggs resembling minute lemons (Fig. 460, *1*) on the undersides of the elm leaves, usually about 25 in a place. The slug-like larvæ hatching from these eggs are yellow in color, spotted with black. They feed for about 3 weeks, and when full-grown, are ½ inch in length. They then crawl down the trunk of the tree, gathering in large masses about the base of the tree or in any shelter near-by. Here they pupate, emerging as beetles in from 1 to 2 weeks. There are from two to three generations a year, depending on the locality.

Control Measures.—The elm leaf beetle may be held in check so that no damage from it will occur, if the trees are thoroughly sprayed with arsenate of lead, using 3 pounds to 50 gallons of water. The first spray should be applied about a week after the elms have come into full foliage. If only a part of the trees in the neighborhood have been sprayed, it will be necessary to make another application for the second generation of beetles, putting this application on about midsummer. Many of the larvæ may be killed about the base of the tree when they have come down to pupate, by spraying with a strong soap solution. Ordinary laundry soap at the rate of 3 ounces to 1 gallon of water, applied to the bodies of the larvæ, will kill them.

References.—Conn. Agr. Exp. Sta. Bull. 155, 1907; *N. Y. State Museum Bull.* 156, 1912; *Ore. Agr. Exp. Sta. Circ.* 92, 1920.

Bagworm[1]

Importance and Type of Injury.—Infested trees have the foliage stripped or very much ragged. Numerous sacks or bags (Fig. 461) from ¼ to 1½ inches in length hang down from the twigs, leaves, branches, and sometimes on the bark of the trunk. During the summer these bags contain dark-brown, shiny-bodied worms.

Trees Attacked.—This insect is a very general feeder, attacking practically all deciduous and evergreen trees.

Distribution.—The bagworm is generally distributed over the Eastern United States, being more severe in the south-central parts of the country.

Life History, Appearance, and Habits.—The winter is passed in the form of pale, whitish eggs, inside the bag in which the female worm lived

[1] *Thyridopteryx ephemeræformis* Haworth, Order Lepidoptera, Family Psychidæ.

during the summer. These eggs hatch rather late in the spring, after the trees have come into full foliage. In the latitude of central Illinois, they hatch about June 10 to 15. The young worms on hatching almost immediately spin a silken sack or bag about themselves, and then begin feeding on the foliage. As they feed, they attach to the bag bits of the leaves on which they are feeding. The bag is carried about by the insect wherever it goes, the larva merely protruding the front end of its body from the bag. It is almost impossible to draw the larva out of the bag without crushing its body. This bag offers almost complete protection

FIG. 461.—Cases of the bagworm, *Thyridopteryx ephemeræformis* Haworth, fastened to twig of cedar, as found in winter. Natural size. (*From Ill. State Nat. Hist. Sur.*)

from birds, but the worms are parasitized by several species of flies and wasp-like parasites. The worms are of a brown color over the entire body and head, and when full-grown the insect measures about 1 to 1¼ inches in length, the bags at that time being from 1½ to 2½ inches in length. They pupate within the bag during early September, attaching the bag to the twigs with a thread of silk (Fig. 461). The male changes to a black-winged moth, with a wing expanse of about 1 inch. These moths emerge from the bags and fly actively. The female moths, however, are wingless and never leave their bags, merely protruding their bodies from the tip of the bag during mating, and then retreating within the bag, where they deposit their eggs and shortly afterwards die.

Control Measures.—On small trees, or those that can be readily reached, a thorough clean-up of the bags during the winter by hand

picking and burning, will effectively control the insects. This method is one of the best to use when infestations are first starting, but for a general infestation over shade trees in a neighborhood, the most effective control is spraying. Arsenate of lead should be used at the rate of 4 pounds to 50 gallons of water, applying this spray during the latter part of June in the latitude of central Illinois and Ohio, putting on the spray a little earlier to the south. A weaker spray is not effective, as these insects are very hard to poison. Where the bags are collected, care should be taken that they are removed from the trees and burned, as if they are merely thrown about the ground, the eggs will hatch, and many of the worms will find their way to the trees.

Reference.—*Mo. Agr. Exp. Sta. Bull.* 104, 1912.

Catalpa Sphinx[1]

Importance and Type of Injury.—This is one of the most serious insect pests of the catalpa tree. Infested trees will have the leaves eaten off by dark or black caterpillars from 1 to 3 inches in length with dark-green markings on their bodies, and a sharp horn at the tip of the abdomen (Fig. 462). The markings vary greatly in different individuals.

Trees Attacked.—Catalpa.

Distribution.—This insect is widely distributed in the United States, but is of no importance in the most northern or western states.

Life History, Appearance, and Habits.—The winter is passed as brown naked pupæ in the soil, 2 or 3 inches below the surface. These pupæ (Fig. 462, *j*) will be found under and in close proximity to catalpa trees. The moths (*k*) emerge shortly after the catalpas have come into full leaf, and deposit their white eggs in masses on the undersides of the leaves. Sometimes as many as 1,000 eggs have been found in a single mass. The moths are of a general gray color with a wing expanse of from 2½ to 3 inches. They fly mainly at night, and are seldom seen. The eggs hatch in 10 days to 2 weeks, and the young caterpillars at once begin feeding on the foliage. At first, they feed in groups (*b*, *b*), but later separately. The full-grown caterpillars are about 3 inches in length, with a moderately large black horn protruding from the tip of the body. The backs of the worms are often almost completely covered with the whitish cocoons of a wasp-like parasite.[2] Upon becoming full-grown, they go down the trunk of the tree, enter the ground, and there change to the pupal stage. There are two generations of the insect each season, at 40° north latitude, the second generation of worms appearing on the trees during late August and early September.

Control Measures.—While these worms are large and very ravenous feeders, they may be very easily controlled by spraying or dusting.

[1] *Ceratomia catalpæ*, Boisduval, Order Lepidoptera, Family Sphingidæ.

[2] *Apanteles congregatus* Say, Order Hymenoptera, Family Braconidæ.

Spraying with arsenate of lead, at the rate of 2 pounds to 50 gallons of water, applying the spray as soon as any of the caterpillars are noticed on the leaves, will afford almost complete protection. Dusting with arse-

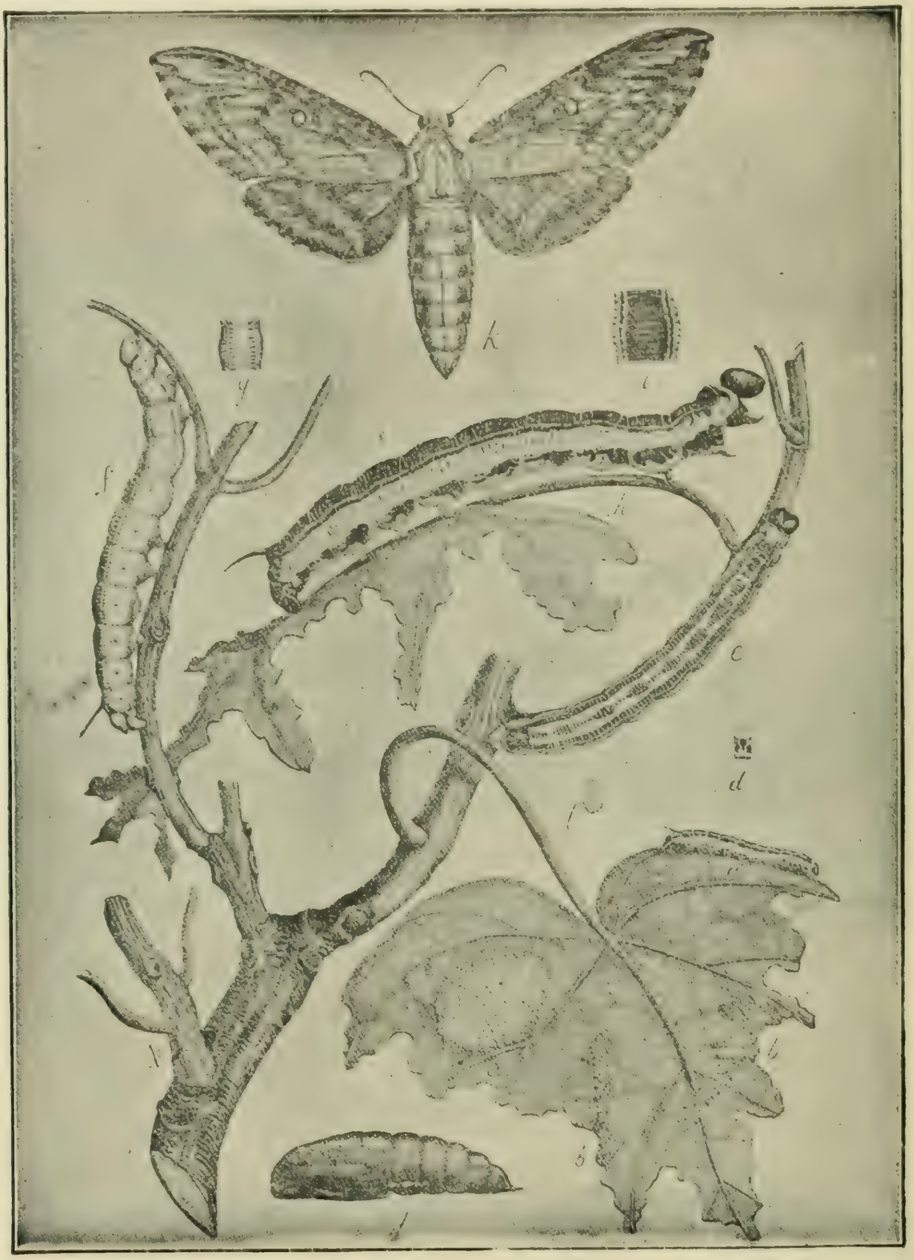


FIG. 462.—Catalpa sphinx, *Ceratomia catalpæ* Boisduval. Above at *k*, adult female moth; at center (*e*, *f*, *h*) three caterpillars stripping leaves; below at *a*, an egg mass on leaf; and at *j* the pupa; *b* and *c*, partly grown larvæ; *l*, a single egg enlarged; *d*, *g*, and *i* show the variation in color pattern of single segments of larvæ from above. Slightly reduced. (*From Ohio Agr. Exp. Sta.*)

nate of lead, or calcium arsenate, at the rate of 8 to 10 pounds per acre is also very effective. The insects are heavily parasitized, and severe outbreaks usually last for only 1 or 2 seasons, with a break of about the same

period before the worms will again become numerous enough to strip the trees completely.

Reference.—Ohio. Agr. Exp. Sta. Bull. 332, pp. 238–241, 1918.

Walnut Caterpillar[1]

Importance and Type of Injury.—Walnut, hickory, and other trees, have the branches or entire trees stripped of their leaves during July and August. Masses of large, dark-bodied white-haired caterpillars, cluster on the trunk of the tree (Fig. 464), or feed together on the leaves.

Trees Attacked.—Walnut, butternut, pecan, hickory, and occasionally peach, willow, honey locust, apple, and oak.

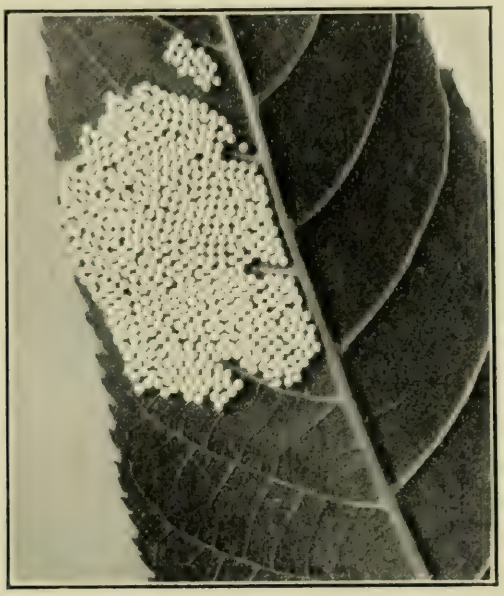


Fig. 463.—Walnut caterpillar, egg mass, about twice natural size. (*From Ohio Agr. Exp. Sta. Bull.* 332.)

Distribution.—The insect is common throughout the eastern and southern United States.

Life History, Appearance, and Habits.—The winter is passed in the form of a brown naked pupa about 1 inch or a little over in length. The pupæ will be found from 2 to 6 inches beneath the surface of the soil in the vicinity of the trees on which the insect feeds. The adult moths emerge from these pupæ during late June and July. They measure 1½ to nearly 2 inches across the expanded wings. The wings are of a general light brown, with dark-brown, wavy lines running across them. The hind wings are lighter brown without the crosslines. A dark-brown tuft of hair covers the back of the thorax. The moths are strong fliers, and deposit their eggs in masses of 200 to 300 (Fig. 463) on the underside of the leaves of their food plants. These hatch in about 2 weeks into small reddish worms with black heads. As they grow, the color of the body changes to brown,

[1] *Datana integerrima* Grote and Robinson, Order Lepidoptera, Family Notodontidæ.

and later, in the full-grown stage, to black. They are covered with rather soft, long, frowzy white hairs. The full-grown caterpillar is 2 inches or a little over in length. They feed together, several hundred in a place, and a single colony will often strip one or two branches on the tree. As the worms grow, they have a peculiar habit of coming down the tree to change their skins. The entire colony crawls down the trunk at the same

FIG. 464.—A cluster of walnut caterpillars, *Datana integerrima* Grote and Robinson, molting on the trunk of a walnut tree. (*From Ohio Agr. Exp. Sta. Bull.* 332.)

time, so that one will often find masses of worms, from 4 to 8 inches across, clinging to the trunk of the tree (Fig. 464). The shed skins remain on the tree trunk, having much the appearance of dead worms. On becoming full grown, the caterpillars leave the tree, crawl away for a short distance, and enter the ground, where they later change into the brown pupal stage. There is but a single generation over most of the range of the insect, although possibly two in the southern areas where it occurs.

Control Measures. The most effective method of controlling this insect is to spray the infested trees with arsenate of lead at the rate of 2 pounds to 50 gallons of water. This spray should be applied as soon as the caterpillars are seen feeding upon the foliage. On small trees, the colonies may be removed before much of the foliage has been destroyed, using a pole pruner, and cutting off and burning the few leaves on which the caterpillars are starting to feed. If the trees are watched every day, it is possible to crush many of the caterpillars when they come down the trunk to shed their skins.

Spraying, however, is the only really effective remedy that can be depended upon to protect trees from all damage by these insects. Banding trees with sticky material is of no benefit, as the moths do not crawl up the trunk to deposit their eggs.

References.—*U. S. Dept. Agr. Farmers' Bull.* 1169, 1921; *N. Y. State Museum Mem.* 8, Vol. 1, p. 303, 1905.

FIG. 465.—Larvæ of the white-marked tussock moth, *Hemerocampa leucostigma* Smith and Abbott, slightly enlarged. (*From U. S. D. A. Farmers' Bull.* 1270.)

WHITE-MARKED TUSSOCK MOTH[1]

Importance and Type of Injury.—This insect is usually considered more of a shade-tree than an orchard pest, but sometimes, especially in the North, it becomes destructive in orchards. The foliage is skele-

[1] *Hemerocampa leucostigma* Smith and Abbott, Order Lepidoptera, Family Lymantriidæ.

tonized by yellowish-black, hairy, striped caterpillars. They are easily recognized by the three pencil-like tufts of long black hairs that project, one on each side of the head and the third from the tail, and two bright-red spots on the back towards the hind end. Fruits are sometimes scarred by the shallow feeding of the caterpillars on the surface.

Trees Attacked.—Apple, pear, quince, plum, and other deciduous fruits and almost all shade trees except conifers. Especially destructive to shade trees in cities.

Fig. 466.—The tussock moth, *Hemerocampa leucostigma* Smith and Abbott, adult female clinging to the cocoon from which she has emerged. Natural size. (*From Ohio Agr. Exp. Sta. Bull.* 332.)

Distribution.—Eastern United States and Canada, westward to British Columbia and Colorado. Less troublesome in the South.

Life History, Appearance, and Habits.—The winter is passed in the egg stage. The eggs are laid in conspicuous masses (Fig. 467) of 50 to 100, attached to the trunk, branches or dead leaves of the tree, usually on top of the dirty-grayish cocoon from which the female moth emerged. The eggs are covered with a mass of white, stiff substance, having the appearance of hardened lather. They hatch in the late spring into light-brown, hairy caterpillars, marked as described above (Fig. 465), which feed on the surface of the leaves, skeletonizing them. They

become full-grown during July, spin their cocoons on the trunk and branches, and within these transform to the pupal, and later to the adult, moth stage. As is the case with cankerworms, the male moths, which are dark brown in color, are well provided with wings and are strong fliers, while the wings of the female are mere stubs and cannot be used at all for flight (Fig. 466). The moths emerging during midsummer soon deposit eggs for a second generation of caterpillars, which feed upon the trees during the latter part of August and early September. They transform to moths again during September and October. The females lay eggs on their cocoons and these carry the insect through

FIG. 467.—Eggs of the white-marked tussock moth as laid by the wingless female on top of her cocoon. (*From Ill. State Nat. Hist. Sur.*)

the succeeding winter. In the more southern part of its range the tussock moth may produce a third generation.

Control Measures.—On shade trees it is often possible to hold this insect in check by daubing the overwintering egg masses with creosote, as described for the gypsy moth (p. 692). On fruit trees, an application of arsenate of lead, at the rate of 1 pound to 50 gallons of water, should be given as soon as the caterpillars appear in numbers upon the trees. Outbreaks of the tussock moth, while often causing considerable damage for 1 or 2 seasons, are usually short-lived because of the presence of numerous insect parasites that always reduce outbreaks.

Reference.—*N. Y.* (*Geneva*) *Agr. Exp. Sta. Bull.* 312, 1909.

Gypsy Moth[1]

Importance and Type of Injury.—Shade, fruit, and woodland trees are stripped of their leaves during June and July by small, flattened, pale-brown caterpillars with long tufts of rather stiff brown and yellow hairs projecting from the sides of the body. The caterpillars (Fig. 468) are about 2 inches long when full-grown. There are five pairs of blue tubercles followed by six pairs of red tubercles, arranged in two rows down the back. This imported insect is one of the most serious pests

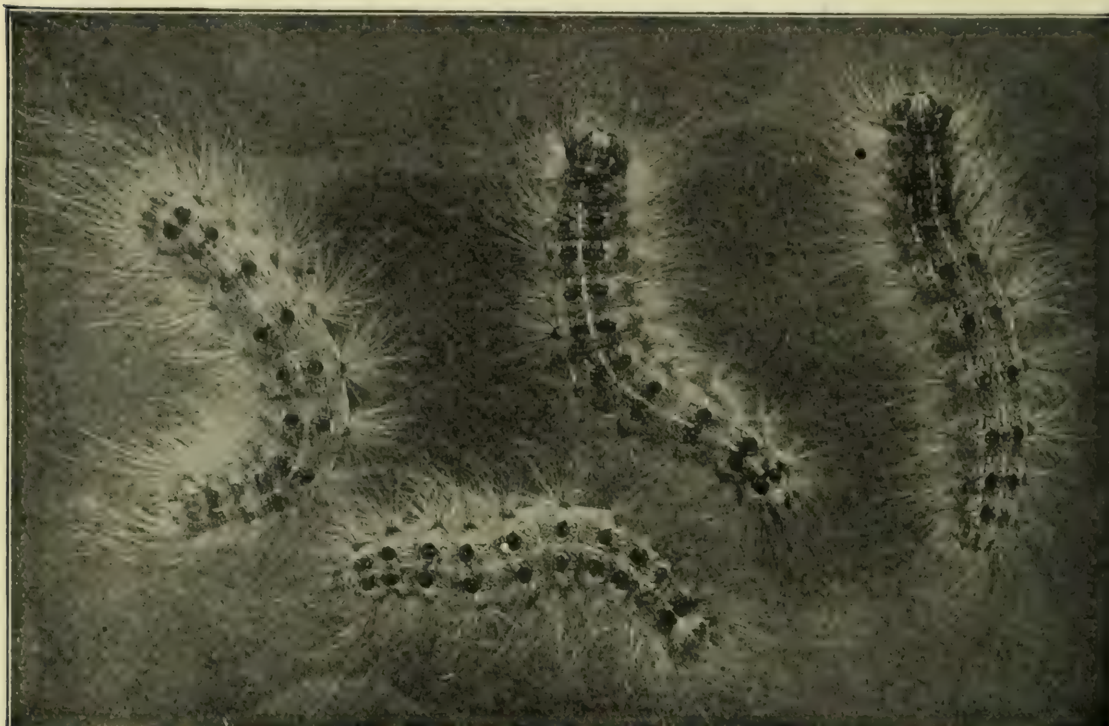


FIG. 468.—Full-grown larvæ of the gypsy moth, *Porthetria dispar* Linné. The tubercles on the back of the segments are blue on the front half of the body, and red on the rear half. Natural size. (*From U. S. D. A.*)

of shade trees, both evergreen and deciduous trees, stripping the foliage and often causing the death of the trees. Millions of dollars have been spent in fighting this pest in the New England States.

Plants Attacked.—This caterpillar feeds on nearly all deciduous and evergreen trees and shrubs. It also attacks the foliage of some garden plants and is frequently a very serious pest of cranberries. More than 500 different species of plants are included in the list of those fed upon by this insect.

Distribution.—So far as known, the insect is confined to the New England states, a small area in southeastern Canada and an area in New Jersey. It was originally brought into this country from Europe in 1869.

[1] *Porthetria dispar* Linné, Order Lepidoptera, Family Lymantriidæ.

Life History, Appearance, and Habits.—The winter is passed in the egg stage. These eggs are laid in masses of from 15 to several hundred. They are covered with a coating of hair and are about the color of chamois skin. In the latitude of Boston, the eggs hatch during late April and early May. The young caterpillars are very voracious feeders. During the first two instars they do not feed on evergreens, but as they grow larger readily attack them. They become full-grown during the first half of July, and spin a very loose light cocoon on the trunk of the tree and other near-by objects. Within this they change to a dark-brown pupal stage. The moths begin emerging during the latter part of

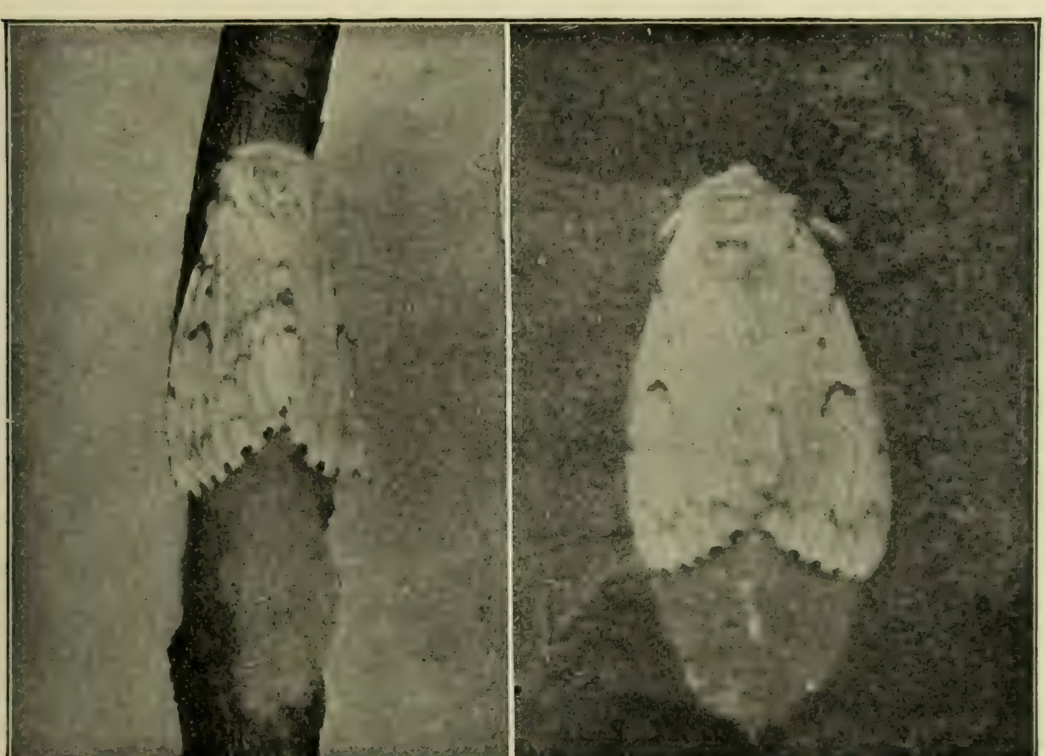


FIG. 469.—Adult females of the gypsy moth, *Porthetria dispar* Linné, depositing their egg-masses. Enlarged about one-half. (*From U. S. D. A.*)

July. The males are dark brown in color, with small bodies well equipped with wings; and are strong fliers. The female moth (Fig. 469) is of light-buff color, with irregular darker markings across the wings. She is a very heavy-bodied insect and is able only to flutter along the ground but cannot travel by sustained flight through the air. After mating, she deposits her eggs on various objects, frequently on the undersides of stones, or on buildings, the trunks of trees, or in many other places. There is but one generation of the insect each season. The adult moth is incapable of flight, and it has been found that most of the spread of the insect occurs when the young larvæ are blown by the wind, during the first and second instars of their existence. At this time they are carried long distances, having been taken on islands off

the New England coast, where they must have traveled through the air for at least 20 miles. The young larvæ are equipped with hollow hairs, which greatly increase their buoyancy and enable them to drift with the wind as above described.

Control.—There are several effective control measures to use against this insect. During the winter, the egg masses may be killed by touching them with brushes wet with crude creosote. The larvæ feed at night, coming down the trunk of the trees and hiding away in some sheltered place during the day. In the infested areas, bands of burlap are placed around the trees and these are examined each day and the larvæ which have sought shelter under them are killed. The most effective method of control is by spraying, using a high-power outfit and drenching both shade and woodland trees with a strong mixture of arsenate of lead. In order to kill the mature caterpillars, as much as 10 pounds of arsenate of lead in 100 gallons of water is necessary. During the last 20 years the federal Bureau of Entomology has been actively engaged in importing parasites of the gypsy moth from Europe and Asia. A large number of these parasites are now established in heavily infested areas in New England, and are doing very effective work in keeping down this destructive insect. This insect has cost the State of Massachusetts more than a million dollars a year, for the past 20 years. It has been confined to the eastern part of the United States by strict quarantine measures. At present, a strong effort is being made to stop its westward spread across the line of the Hudson River and Lake Champlain valleys. Anyone seeing an insect which they suspect of being the gypsy moth outside of the known area of infestation, should forward it to the entomologist of their state at once, as it is possible to clean up isolated infestations at no great expense, but if the insect should become established over the country, it would certainly cause losses amounting to many millions of dollars a year.

References.—*Dom. Canada Dept. Agr. Bull.* 63, n. s., 1926; *U. S. Dept. Agr. Farmers' Bull.* 564, 1913; *U. S. Dept. Agr. Farmers' Bull.* 1335, 1923; *U. S. Dept. Agr. Bur. Entomol. Bull.* 87, 1910.

Brown-tail Moth[1]

Importance and Type of Injury.—This insect is a very important pest of deciduous shade and fruit trees. The damage is caused by dark-brown, hairy caterpillars stripping the leaves from trees. The insect also causes great annoyance and sometimes serious illness to human beings because of the fact that its hairy body is equipped with nettling hairs, which on entering the skin cause a rash that is very irritating. There have been some instances where the insect probably

[1] *Nygmia phæorrhoea* Donovan, Order Lepidoptera, Family Lymantriidæ.

caused death from large numbers' of the hairs being breathed into the lungs.

Plants Attacked.—Nearly all deciduous trees and shrubs: rare on buckeye, ash, hickory, chestnut; never on evergreens.

Distribution.—The insect is a native of Europe and was introduced into eastern Massachusetts, on imported nursery stock, about 1897. It now occurs in all of the new England states and has extended its range northward into southeastern Canada.

Life History, Appearance, and Habits.—The insect passes the winter in the form of very tiny caterpillars, living together in colonies of 25 to 500. Each colony webs together several leaves and attaches them firmly to twigs, by threads of very tough silk. These winter nests (Fig. 470, *2*) are quite conspicuous on the trees. The caterpillars are so well protected within these nests that they can withstand very low temperatures. As soon as the leaves start coming out in the spring, the little caterpillars become active and crawl out from the nest to feed on the tender foliage. They go back within the nest at night, for a time, but as they become larger remain on the foliage. In the latitude of Boston they become full grown about the last of June. The full-grown caterpillars (Fig. 470, *3*) are about 1½ inches in length, dark brown in color, with a broken white stripe on each side of the body and a bright-red tubercle on the back of the eleventh and of the twelfth body segment. They seek some sheltered place where they transform to the pupal stage (*4*, *5*), and remain in this stage for about 3 weeks, and then emerge as medium-sized moths. These moths (Fig. 470, *6*, *7*) have a wing expanse of a little over 1½ inches. The wings and thorax are pure white. The abdomen is mostly brown, with a very conspicuous tuft of chestnut-brown hairs at the tip. These moths are strong fliers, flying in large swarms at night. Sometimes in localities where they are abundant, they literally cover the sides of telephone poles and buildings, giving them the appearance of being covered with snow. Each moth deposits about 200 eggs on the foliage of the food plants. These eggs are laid in small masses (Fig. 470, *1*) and are covered with brown hairs, giving them a dark, chestnut-brown color. The eggs hatch during August or early September and the young caterpillars from each egg mass or from several near-by egg masses, feed together for a short time on the terminal leaves of twigs and branches and then spin the web shelter in which they pass the winter. The insect has been shipped to many parts of the world on nursery stock in these winter webs. There is one generation a year.

Control.—The best and most effective method for controlling the brown-tail moth is to spray infested trees during the early spring when the caterpillars have started to feed. From 4 to 5 pounds of arsenate of lead will have to be used in each 100 gallons of water. In

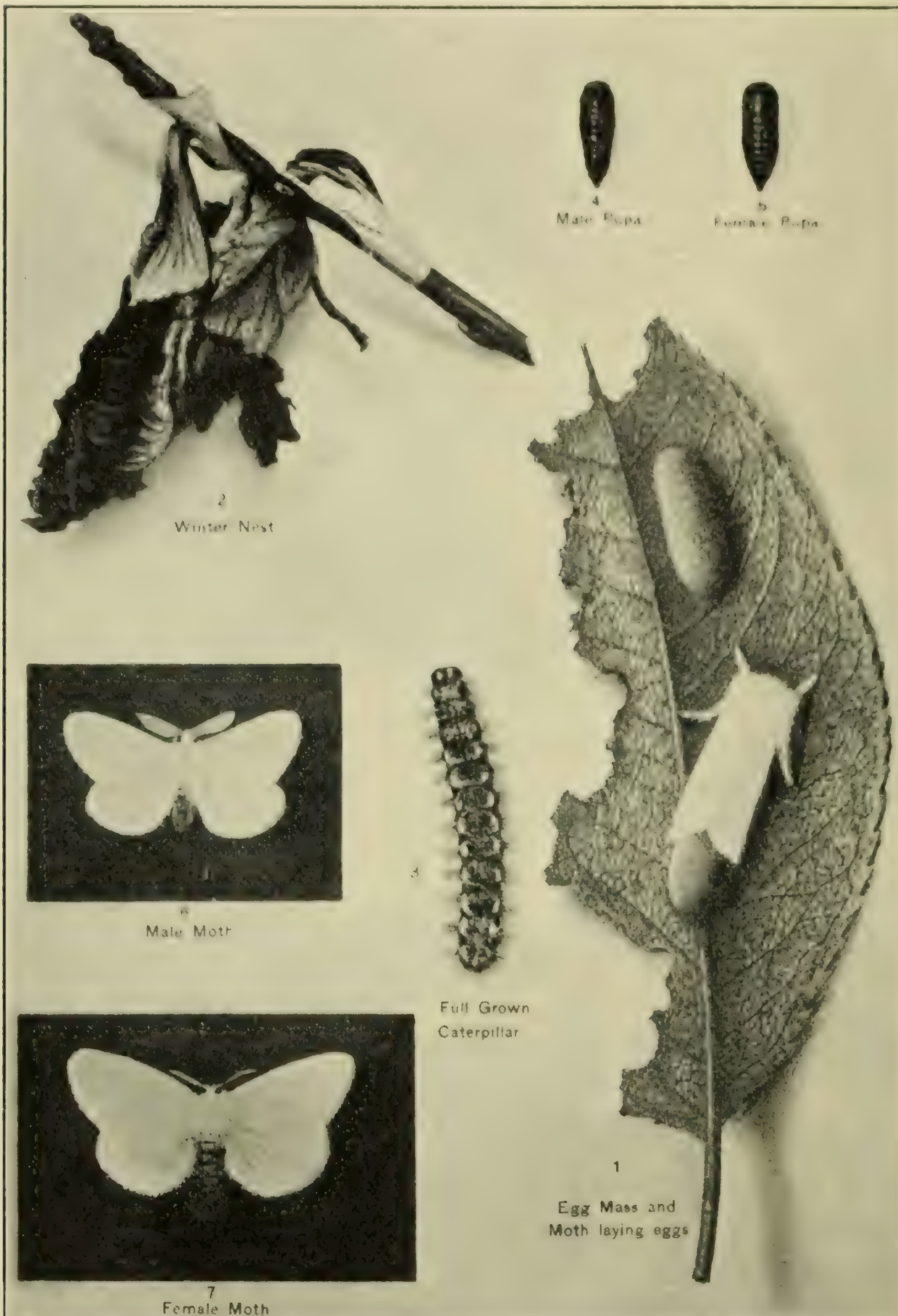


FIG. 470.—The brown-tail moth, *Nygmia phæorrhoea* Donovan, showing the various stages of the insect and a winter nest about natural size. (*From Mass. State Forester.*)

light infestations, much can be done in keeping down the numbers of the insect by cutting off and burning the winter webs. After a little practice, these webs can be easily detected on the tips of the bare branches, and, with the aid of a long pole pruner and a ladder, nearly all the webs can be removed from the trees and burned. During the last several years the insect has been greatly reduced in numbers due to the presence of certain diseases; and for the last 5 years has been of no great economic importance.

References.—*Dom. Canada Dept. Agr. Bull.* 63, n. s., 1926; *U. S. Dept. Agr. Farmers' Bull.* 564, 1913; *U. S. Dept. Agr. Farmers' Bull.* 1335, 1923; *U. S. Dept. Agr. Bur. Entomol. Bull.* 87, 1910.

CHAPTER XX

GREENHOUSE INSECTS

The insects that attack greenhouse crops are the same as those that attack related crops in the field. Some of these insects are field pests only in the South, but have adapted themselves to the semitropical conditions found in greenhouses in the North. It would seem at first thought that insects could be easily controlled in greenhouses, where climatic factors can be largely regulated by man; but this is far from being the case. Conditions must be maintained in the greenhouse to give a maximum rate of growth to the crop, and such conditions are frequently very favorable for the insects attacking the crops. The cost of producing crops under glass is high, and the loss of 10 to 25 per cent of the crop from attacks by insects generally means that the entire operation of producing and marketing the crop has been carried on at a loss to the grower. Crops grown under glass are more easily injured by heavy applications of insecticides, or other insect-control measures that affect the plants, than the same crops grown in the open. For this reason, much greater care must be exercised in the control methods employed.

The best way to prevent damage by insects to greenhouse crops is to keep the insects out of the houses. This may be done by careful inspection of all plants brought into the houses, and by thoroughly cleaning up the houses by heat or heavy fumigations in the intervals between crops. Open range houses are, on the whole, more difficult to keep free of insects than those built in sections, as some part of the open range house is nearly always occupied by a crop in some stage of growth. Under such conditions, strong fumigations which will kill nearly all plant and animal life cannot be used for cleaning up the house.

In order to avoid insect injury in greenhouses, three measures should be followed: (1) Before a crop is put in, or the soil placed in the benches, the houses should be cleaned out as thoroughly as possible, and if they have recently been infested with insects, a thorough fumigation with hydrocyanic acid gas should be given at a dosage equal to 1 ounce sodium cyanide to 100 cubic feet of space (see page 255). Such a fumigation will kill practically all insect life in any stage that may be present in the house. (2) A careful inspection should be made of the soil being brought into the benches, to make sure that this soil does

not contain wireworms, white grubs, eel worms, cutworms, or other insects that may be injurious to greenhouse crops. If the soil is infested, it should be sterilized with steam. (3) All plants brought into the greenhouse should be inspected to make sure that they are free from insect infestation. Many florists have suffered serious losses because of bringing a few infested plants into their houses, and thus starting an infestation which, before it was noticed, had spread throughout the entire range of their greenhouses.

Many of the best accounts of the life histories, habits, and control of greenhouse insects are contained in general publications dealing with this class of insect pests. Some of these publications are here listed, and should be used as general references for further information on the insects treated in this chapter.

References.—Dom. of Canada, Dept. Agr. Bull. 7, new series, 1922; *N. J. Agr. Exp. Sta. Bull.* 296, 1916; *Fifth Rept. State Entomol. S. Dak.* 1924; *U. S. Dept. Agr. Farmers' Bull.* 1306, 1923; *U. S. Dept. Agr. Dept. Bull.* 1357, 1926; *Mich. Agr. Exp. Sta. Special Bull.* 134, 1924; *U. S. Dept. Agr. Farmers' Bull.* 1362, 1923; *Twenty-seventh Rept. Ill. State Entomol.* 1912.

KEY FOR THE IDENTIFICATION OF INSECTS INJURIOUS TO GREENHOUSE PLANTS

A. Insects that suck the sap of the plants:

1. Greenhouse plants show a sickly appearance, the foliage turning yellow. Numerous, brown or brownish-gray, flattened, motionless scales adhere to the undersides of the leaves, or along the stems, especially at the leaf axils. Scales usually of sufficient size to be easily seen, some up to ⅛ inch in diameter. The scale covers the body of the insect, but is easily lifted from it. *Armored scales*, page 700.

2. Foliage plants, such as oleander, fern, palm, Ficus, and Vinca having much the same appearance as in *A*, 1. Scales somewhat larger and adhering more tightly to the plants. Scales much more conspicuous than in *A*, 1, usually very convex. Scale covering cannot be lifted off from the body of the insect, but forms a distinct part of the body wall. *Tortoise scales*, page 704.

3. Plants, particularly foliage plants, such as Coleus, orchids, poinsettias, ivy, and many others, with whitish clusters of soft-bodied insects, up to ¼ inch long, at the axils of the stems and leaves and along the stems. These insects have many whitish, waxy filaments protruding from the body. These filaments are so thick as to give the body a distinct bluish-white appearance. Insects seldom move unless disturbed. *Mealy bugs*, page 704.

4. Plants infested in much the same way as in *A*, 3, by insects with rather small, dark-colored bodies, with rows of short waxy filaments radiating around the outer margin of the body, and forming a waxy tube extending back from the body several times its length. *Greenhouse Orthezia*, page 707.

5. Greenhouse plants having a weakened appearance; frequently with the leaves curled, the young growth distorted, and often coated to some extent with sticky honeydew. Small, winged or wingless aphids, or plant lice, of various colors, sucking the sap from the more tender parts of the plants, buds, and blossoms. *Greenhouse aphids*, page 707.

6. Under surface of the leaves, with small, oval, flat, pale-green, motionless insects, less than $^1/_{30}$ inch in length, adhering to them. Many, tiny, four-winged, snow-white flies on the underside of the leaves. These flies leave the plants in swarms

when disturbed. Plants more or less covered with a coating of glazed, sticky material on which a sooty black fungus is frequently growing. *Greenhouse whitefly*, page 709.

7. Surface of the leaves whitened with many small flecks of light green or yellow. Tips of the leaves curling up and dying. Flower buds producing distorted blossoms which open only on one side. Undersides of the leaves with numerous black spots. General vigor of the plants greatly reduced by the feeding of many very small yellow or black, very slender, active insects. *Greenhouse thrips*, page 710.

8. Plants with pale blotches or spots showing through the leaves, or with the entire leaf having a light color, often drying up or turning a reddish-brown about the margins. Fine silk threads are spun on the under sides of the leaves, or formed into webs which entirely cover the surface of the plant. Minute, six- or eight-legged, greenish or yellowish mites crawling about on the webs or under side of the leaves. *Greenhouse red spider*, page 712.

9. Cyclamen with the leaves much distorted, buds gnarled and knotty in appearance, usually failing to open; flowers on infested plants when open are streaked and blotched in appearance and quickly die. Infested foliage shows pockets or depressions in the leaf, or dark purplish areas, often covered with small cracks, on the leaf surface. Tiny, white, or pale-brown mites, with three or four pairs of legs, working in the infested flowers, on the leaves, and about the base of the plants. *Cyclamen mite*, page 725.

B. Insects that chew the leaves:

1. Under surface of the leaves eaten off by pale-green, very active caterpillars up to ¾ inch long. Such leaves are often covered with a light web enclosing, several leaves, or drawing parts of a single leaf together. *Greenhouse leaftyer*, page 714.

2. Injury appearing much the same as in *B*, 1. Small active greenish worms feeding at first as leaf miners, but later eating off the surface of the underside of the leaves. Leaves rolled, or drawn together with light webs. *Oblique-banded leaf roller*. page 716.

3. Ferns with the leaves partly stripped, presenting a very ragged appearance. Newly unfolding leaves gnawed or eaten away. Dark-green, velvety caterpillars, with two wavy white lines down each side of the body, hiding in the soil about the base of the ferns, feeding very actively at night. *Florida fern caterpillar*, page 716.

4. Many kinds of plants cut off at the surface of the ground, or, in some cases, stripped of leaves, by fat, sleek caterpillars or worms of varying sizes and colors. *Cutworms*, page 716.

5. Leaves eaten from the new growth, or buds eaten into, or partly eaten out, by greenish, dark-brown, or yellowish worms with slightly hairy bodies, differing from cutworms in their habit of feeding on the upper part of the plants. Injury most common during the fall months. *Corn earworm*, page 716.

6. Roses with the leaves riddled with small holes, bark of the new growth eaten off, and buds eaten out. Injured plants with most of the feeding roots eaten off by small, curved-bodied, whitish grubs. Brownish or brownish-black, very active beetles, about ⅛ inch long, feeding on the leaves. *Strawberry rootworm*, page 717.

C. Insects that make galls or mine in the leaves:

1. Chrysanthemums with small blister-like, cone-shaped galls on the upper surface, and occasionally on the under surface, of the leaves. Leaves curled and stems of heavily infested plants crooked and distorted. Flowers opening imperfectly if at all. Small, gnat-like flies, about 1/14 inch in length, and of a reddish-orange color, crawling about over the leaves. Minute yellowish-white maggots in the galls on the leaves and stems. *Chrysanthemum midge*, page 718.

2. Flower buds and leaves of roses much distorted; terminal growth and buds dying and turning brown. An examination of such buds will show many small, white

to orange-colored maggots, up to ½ inch long, feeding on the plant tissue within the buds. Small silken cocoons just under the surface of the soil about the plants. *Rose midge*, page 719.

3. Leaves of chrysanthemum or marguerite with irregular light-colored mines extending over their surface. When badly infested, the leaves may dry up, but usually remain attached to the plants. Heavily infested plants are stunted and produce small, inferior flowers. *Chrysanthemum leaf miner* or *Marguerite fly*, *Phytomyza chrysanthemi* Kowarz, (see *U. S. Dept. Agr. Farmers' Bull.*, 1362, 1922).

D. Insects that attack the roots or bulbs:

1. Plants presenting a somewhat sickly appearance, with no visible injury to the part above the surface of the ground. Roots showing minute brownish scars or tunnels along their surface. Very small, somewhat thread-like, active white maggots, not over ¼ inch long, embedded in the root tissues, or working in the soil about the roots. *Fungus gnats, or Sciara maggots*, page 720.

2. Narcissus and related bulbs with scars on the base of the bulbs, the bulbs soft and frequently rotting. An examination of the bulbs shows whitish or yellowish-white fat maggots inside the bulbs, eating out the plant tissue. Maggots, when full-grown, are from ½ to ¾ inch in length. *Narcissus bulb fly*, page 721.

3. Bulbs appearing as in *D*, 2, but containing smaller maggots of a grayish-yellow color, with bodies markedly wrinkled. Many maggots often occurring within one bulb. The maggots vary in size up to ½ inch in length. *Lesser bulb fly*, page 722.

4. Greenhouse plants sometimes cut off just below the surface of the ground, or wilting and dying, without visible injury to the part of the plant above the ground. Examination of the roots will show large curved-bodied, brown-headed white grubs with six rather conspicuous legs, feeding on the underground parts of the plant. *White grubs*, page 723.

5. Appearance and injury much the same as in *D*, 4, but with underground parts of the plant eaten off, or bored through, by shining, hard-bodied, brown, slender worms up to 2 inches in length. *Wireworms*, page 303.

6. Plants of various species that are grown from bulbs turn a sickly yellow, failing to produce flowers; or, if producing flowers, with the flowers much distorted. Leaves stunted, and plants generally of a very unhealthy appearance. Examination of the bulbs shows numerous pale-white, six- or eight-legged mites, sheltering and feeding behind the bulb scales. Infested bulbs with reddish-brown spots on the bulb scales. *Bulb mite*, page 723.

E. Various small creatures, not true insects, attacking mostly the roots or leaves on the soil surface:

1. Light gray or slate-colored, flat-bodied, distinctly segmented creatures, usually about ½ inch long, with seven pairs of legs, hiding under clods or bits of plant refuse on the surface of the benches, and feeding mainly at night on the roots and tender portions of nearly all greenhouse plants. When disturbed, they usually roll themselves into small tight balls. *Sowbugs or pillbugs* (not true insects), page 726.

2. Hard-shelled, very active, many-legged creatures, up to 2 inches in length, usually with two pairs of legs on each body segment, crawling over the surface of greenhouse benches or hiding under any shelter on the surface of the soil. Bodies usually have a brown or pinkish-brown color. Creatures scuttle about very actively when disturbed. Are most abundant in damp parts of the bench. *Greenhouse millipedes* (not true insects), page 727.

3. Roots and underground parts of stems scarred or eaten off by small, nearly white, very active, many-legged creatures ¼ inch long or less. They are very strongly repelled by light. *Garden centipede, Scutigerella immaculata* (Newport) (See *Jour. Econ. Entomol.* Vol. 21, pp. 357 to 360, 1928).

4. Soft, gray or gray-and-brown-spotted, slimy, soft-bodied creatures, from 1/2 inch to as much as 4 inches in length crawling about on the surface of the soil or on the plants. A sticky, viscid secretion is given off from the body, and on drying forms a shiny trail where the creatures have crawled. Usually abundant only in the damper parts of the greenhouse, where they will be found under decaying wood, flower pots, and other shelters. They feed at night on the plant tissue of many greenhouse crops. *Slugs* or *snails* (not true insects), page 728.

5. Plants presenting a sickly appearance, often somewhat distorted, but with no visible injury to the parts above ground. An examination of the roots will show numerous knots or galls, or the roots distinctly swollen, enlarged, and of a gouty appearance. The cause of the injury can not be seen, except when the roots are examined under high magnification, when numerous, very minute, nearly transparent, worm-like creatures will be found in the tissue of the swollen and distorted roots. *Nematodes or eel worms* (not true insects), page 728.

Scale Insects

Many greenhouse plants are attacked by some 20 to 25 species of scale insects which occur commonly in greenhouses. It is impossible to treat, in this book, all of these different species separately. These species are figured and described by Dietz and Morrison in "The Coccidæ or Scale Insects of Indiana," a bulletin from the office of the State Entomologist of Indiana, 1916.

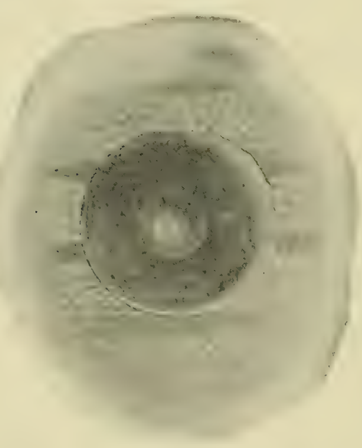


Fig. 471.—Ivy or oleander scale, *Aspidiotus hederæ* (Vallot), on a bit of leaf. About nine times natural size. (*From Ill. State Nat. Hist. Sur.*)

The scale insects found in greenhouses may be divided into two large groups: (*a*) those having a distinct, hard, separable shell or scale over their delicate bodies, known as *the armored scales or Diaspidinæ;* and (*b*) those in which the hard shell is not separable from the body, *the tortoise scales or Lecaniinæ.* The tortoise scales have their bodies rounded and resemble somewhat the back of a turtle.

Armored Scale Insects[1]

In the first class, the armored scales, reproduction takes place by means of eggs, in most cases, although in a few of these species the young are born alive. In cases where the eggs are laid, these eggs are protected by the scale of the mother insect until they hatch. In whichever manner the young are produced, they crawl from beneath the scale of the parent and move about actively for a short time, until, upon finding a location on the plants which seems favorable to them, they insert their thread-like mouth parts through the epidermis of the leaf or bark and begin feeding by sucking the sap. After feeding a short time, they

[1] Order Homoptera, Family Coccidæ.

molt and in this process lose their legs and antennæ. The cast skin is incorporated into the scale, which now forms on the body of the insect and which is composed of fine threads of wax which have exuded from the body wall of the scale and have run together. The female scales molt twice during their life, but always remain under the scale for their entire life. The males, after their second molt, have a more elongated body, and after a third and fourth molt, assume the adult form. In this stage, they are very minute, two-winged, yellowish insects, with antennæ, eyes, three pairs of legs, and a rather prominent long appendage projecting from the tip of the abdomen. They move about actively, seek out the female scales and mate with them, but do not feed in this stage.

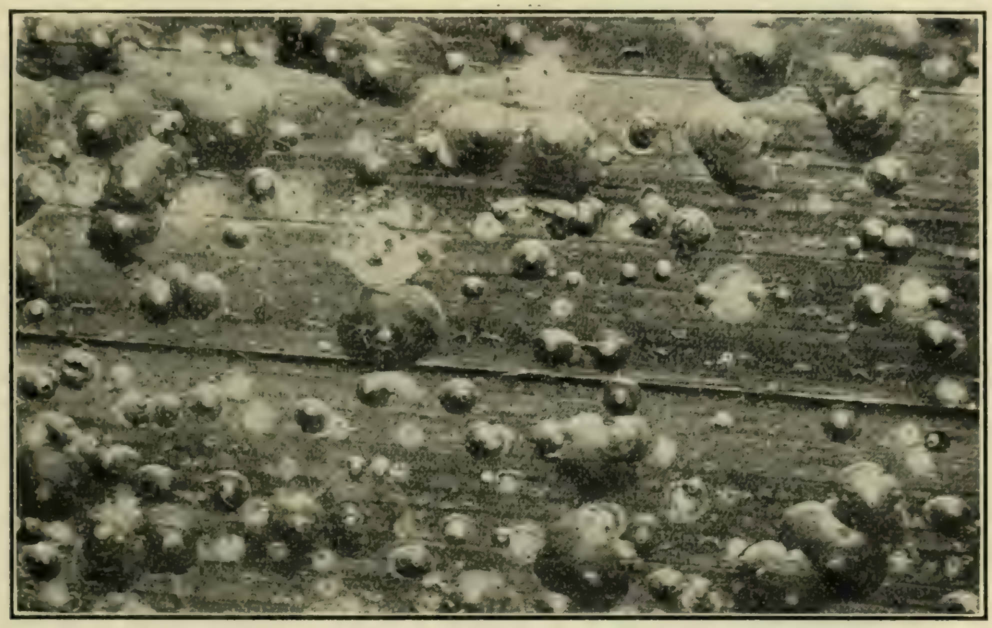


FIG. 472 —The Florida red scale, *Chrysomphalus aonidum* Linné. Scales of adults and nymphs on palm leaf, about six times natural size. (*From Mich. Agr. Exp. Sta.*)

After the female has mated, she continues to feed for some time and produces her eggs, or in the case of a few species as above mentioned, brings forth living young. The life history of all of the armored scales is essentially the same.

A few of these scales, which are most common in greenhouses in the United States are:

Ivy or oleander scale, *Aspidiotus hederæ* (Vallot) (Fig. 471)
Latania scale, *Aspidiotus lataniæ* Signoret
Greedy scale, *Aspidiotus rapax* Comstock
Florida red scale, *Chrysomphalus aonidum* Linné (Fig. 472)
Red or orange scale, *Chrysomphalus aurantii* Maskell (see Fig. 441)
Palm scale, *Chrysomphalus dictyospermi* (Morgan)
Boisduval's scale, *Diaspis boisduvalii* Signoret
Cactus scale, *Diaspis echinocacti* (Bouché)
Rose scale, *Aulacaspis rosæ* (Bouché)
Cyanophyllum scale, *Aspidiotus cyanophylli* Signoret

FIG. 473.—The fern scale, *Hemichionaspis aspidistræ* Signoret. Female on a bit of leaf, about twenty times natural size, on the left. Male on a bit of leaf, about sixty times natural size, on the right. (*From Ill. State Nat. Hist. Sur.*)

FIG. 474.—The thread scale, *Ischnaspis longirostris* Signoret, on a bit of palm leaf. About fifteen times natural size. (*From Mich. Agr. Exp. Sta.*)

Mining scale, *Howardia biclavis* Comstock
Camellia scale, *Fiorinia fiorinia* Targioni
Fern scale, *Hemichionaspis aspidistra* Signoret (Fig. 473)
Thread scale, *Ischnaspis longirostris* Signoret (Fig. 474)
Chaff scale, *Parlatoria pergandei* Comstock

This class of scales attacks a wide variety of plants, including palms, Ficus, lantana, citrus plants, oleander, ivy, hibiscus, rose, and several other greenhouse plants.

Control Measures.—On plants such as palms, or any rather hardy plant, these scale insects may be easily controlled by spraying with a 1 per cent lubricating-oil emulsion. Soft water should be used if possible in preparing this emulsion. For making the emulsion, see page 250. Spraying or washing infested plants with a solution of 1 pound of potash fish-oil soap in 3 gallons of water is effective in cleaning up these scales, if the treatment is persisted in until several applications have been made. With this solution, it is better to wash the infested plants with clear water about 2 hours after the treatment, in order to avoid any possible burning. Fumigation with hydrocyanic acid gas, or with calcium cyanide (see pp. 255, 257), used at the strengths recommended in the table on page 253 is effective in cleaning up infestations by this class of scale.

Fig. 475.—The soft brown scale, *Coccus hesperidum* Linné. Several scales on a bit of leaf, about ~~five~~ 10 times natural size. (*From Canadian Dept. Agr.*)

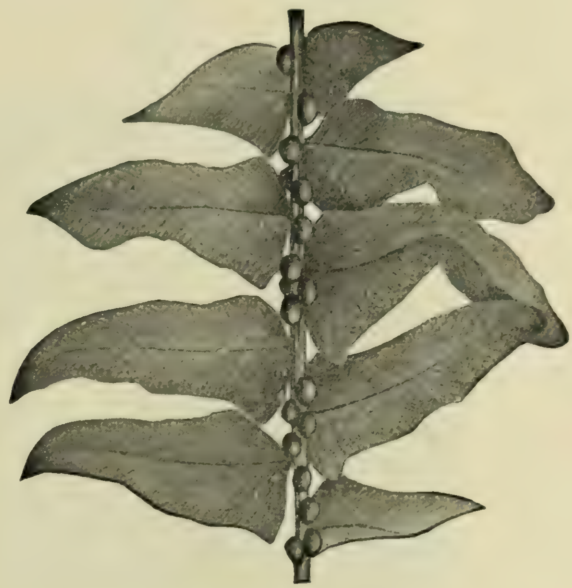


Fig. 476.—The hemispherical scale, *Saissetia hemisphærica* (Targioni), on fern leaf. About natural size. (*From Ill. State Nat. Hist. Sur.*)

Tortoise Scale Insects[1]

This group of scales has a life history somewhat similar to that of the armored scales. The protective shell is, however, not formed of wax and the cast skins, but of the chitinous body wall, very little wax being secreted. The body is generally smooth in outline, and brown, black, or mottled in color. The young female scales may move about for a time after they have begun to feed. They retain their legs and antennæ through adult life (Fig. 402, *a*). They reproduce by means of eggs and living young. The males in this class of scales, also, are winged and similar to those described above. Among the more common scales of this class are:

Soft brown scale, *Coccus hesperidum* Linné (Fig. 475)
Tessellated scale, *Eucalymnatus tessellatus* Signoret
Hemispherical scale, *Saissetia hemisphærica* (Targioni) (Fig. 476)
Black scale, *Saissetia oleæ* (Bernard) (see Fig. 442)
Long scale, *Coccus elongatus* (Signoret) (Fig. 477)

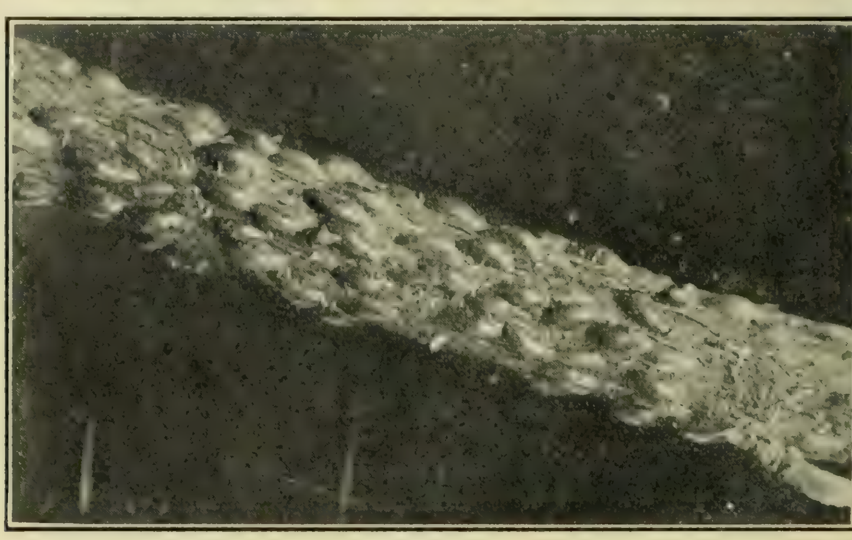


Fig. 477.—The long scale, *Coccus elongatus* (Signoret), adults on stem about twice natural size. (*From Mich. Agr. Exp. Sta.*)

The injury by these scales is very similar to that by the armored scales. The plants attacked include oleander, bay, vinca, croton, cyclamen, fern, palm, Ficus, abutilon, and several other plants.

Control Measures.—Soft scales can be controlled by the same measures as those given for the control of the armored scales.

Mealy Bugs[1]

Mealy bugs are closely related to the scale insects; in fact they belong to the same family. There are several species which occur commonly in greenhouses and on flowering plants in houses. They are all very much alike in their life history, and differ but slightly in appearance. Mealy

[1] Order Homoptera, Family Coccidæ.

bugs may be placed in two groups, (Fig. 478), the citrus or short-tailed mealy bugs,[1] and the long-tailed mealy bug.[2] The long tailed mealy bug gets its name from the long, thread-like, waxy processes which protrude like a tail.

The short-tailed mealy bugs reproduce by means of eggs, and the long-tailed mealy bug reproduces by giving birth to living young. In general, the life history is as follows. The adult mealy bugs deposit their eggs in a compact, cottony, waxy sack, beneath the rear end of the

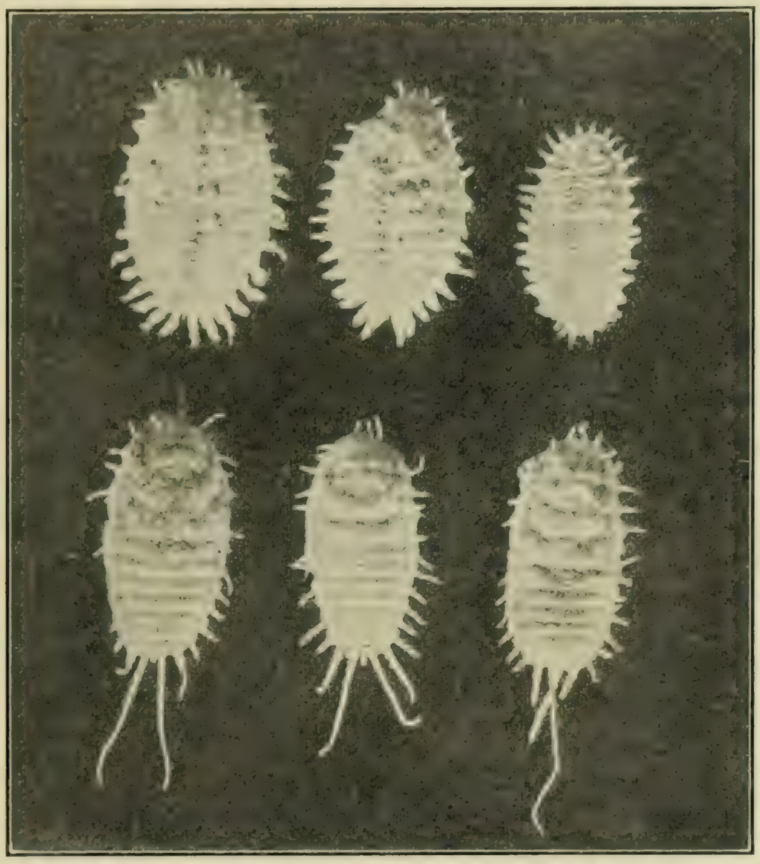


Fig. 478.—Mealy bugs. Upper row, the citrus mealy bugs; lower row, the long-tailed mealy bug. All about ten times natural size. (*From Canadian Dept. Agr. Bull. 7, n. s.*)

body, to the number of 400 to 600. Egg laying continues for 1 or 2 weeks, and as soon as it is completed the female insect dies. These sacks containing eggs will be found chiefly at the axils of branching stems or leaves, but occasionally on other parts of the plant. Under greenhouse conditions, the eggs hatch in about 10 days. The young mealy bugs remain in the egg case for a short time and then crawl over the plants. They are flattened, oval, light-yellow, six-legged bugs, with smooth bodies. They feed by inserting their slender mouth parts into the plant

[1] *Pseudococcus citri* Risso, *Pseudococcus maritimus* (Ehrhorn) and others, Order Homoptera, Family Coccidæ.

[2] *Pseudococcus longispinus* (Targioni), Order Homoptera, Family Coccidæ.

tissues and sucking the sap. Shortly after they begin feeding, a white waxy material begins exuding from their bodies, and forms a covering over the insect. They do not remain fixed, but move about to some extent over the plant, although they are always very sluggish. The female nymphs change but little in their appearance except to increase in size, being about 1/6 to 1/4 inch long when full-grown. The males when nearly grown, form a white case about themselves, and inside of this transform into tiny, active, two-winged, fly-like insects. On emerging from the case, the males fly about actively and mate with the females, but very soon die. The male is incapable of feeding in the adult stage. It takes about 1 month for the completion of a generation under greenhouse conditions.

Many kinds of greenhouse plants are attacked by mealy bugs. They are especially troublesome on the soft-stemmed foliage plants, such as coleus, fuchsia croton, fern, gardenia, and begonia. Among the many other plants attacked are citrus, heliotrope, geranium, oleander, orchids, poinsettias, umbrella plant, ivy, Dracæna, and chrysanthemums.

Control Measures.—The best and most effective method of controlling mealy bugs is to syringe the plants with water applied with as much force as the plants will bear without injury to the leaves. The plants that will not withstand the application of a strong stream of water, may be cleaned by spraying with a nicotine-oleate solution, using the stock solution made according to the following directions:

Nicotine (40 per cent nicotine in the free form)	2½ parts
Oleic acid (red oil)	1¾ parts
Water (rain, or soft,)	4¼ parts

When the oleic acid is added to the nicotine, a soft, soap-like mixture forms. To this the water is added. For tender plants, as coleus and begonia, 1 fluid ounce of the stock solution is diluted with 2 gallons of water. Hardier plants will withstand 1 fluid ounce in each gallon of water. A good syringing of the plants with water the following morning will prevent any possible burning.

Fumigating with hydrocyanic acid gas will sometimes kill the young mealy bugs, but has very little effect on the old ones or eggs. If this method is resorted to, the fumigation should be given at 5- to 7-day intervals for a period of at least 1 month. Tender plants, such as those usually most heavily infested by mealy bugs, will not withstand heavy fumigation of cyanide, ¼ ounce to 1,000 cubic feet of space being about the maximum for such plants in most houses. Spraying or dipping the infested plants with a solution of 1 pound of fish-oil soap in 3 gallons of water, will kill the young mealy bugs. Where such treatment is given, the plants should be washed about 2 hours after treatment, in order to prevent burning by the soap.

GREENHOUSE ORTHEZIA[1]

This insect, also, is a close relative of the scales and mealy bugs. The small, dark-green, wingless bodies of the nymphs are about the size of pinheads, and have rows of minute waxy plates extending back over their bodies. In the case of the female insect (Fig. 479), a white, waxy, fluted egg sack is attached to the body, and extends backward for a distance of two or more times the diameter of the body, the total length being about 1/16 inch. These insects resemble the mealy bugs quite closely in their habits, and can be controlled by the same methods.

FIG. 479.—Greenhouse orthezia, *Orthezia insignis* Douglas, nymph and adult females; the one on the right has the egg sack broken open to show the eggs and newly hatched nymphs. About fifteen times natural size. (*From Mich. Agr. Exp. Sta.*)

APHIDS OR PLANT LICE[2]

Aphids have already been described as pests of many of the outdoor crops (see pp. 314, 442, 503). Everyone who has grown plants for a year or more in the greenhouse is well aware that these little soft-bodied insects are also pests of greenhouse crops. A number of different species of aphids occur in greenhouses, and one or more of them attacks almost every species of plant that is grown under glass. The aphids differ somewhat in size, appearance, and the color of their bodies. Some are green, others brown, reddish, or black in color. Their life histories under greenhouse conditions, are very similar, except for some variation in the length of time which it takes the different species to develop. So far as known, all species continue to go on, generation after generation, the year around, producing only the female forms; and these females on becoming full-grown, give birth to living young without being mated. Under greenhouse conditions, the true sexes do not appear, nor do the insects reproduce by means of eggs. They feed by sucking the sap from the tender plants, often causing the plants to become deformed, the leaves curled and shriveled; and, in some cases, galls are formed on the leaves. The insects are further injurious because of the fact that

[1] *Orthezia insignis* Douglas, Order Homoptera, Family Coccidæ.

[2] Order Homoptera, Family Aphididæ.

some species eject a sweetish honeydew which is attractive to ants, and on which certain sooty-appearing fungi grow. This may render the plants so unsightly as to hinder their sale for any purpose. Aphids are also the carriers of certain diseases of greenhouse plants. Some of the more common species occurring in the greenhouse are:

FIG. 480.—Rose aphids, *Macrosiphum rosæ* Linné, clustered on rosebuds. Several times natural size. Note the predaceous Syrphid-fly larva eating an aphid on the lower part of the left-hand stem. (*From U. S. D. A. Farmers' Bull.* 1362.)

Small green chrysanthemum aphid, *Myzus rosarum* Kaltenbach
Black chrysanthemum aphid, *Macrosiphoniella sanborni* (Gillette)
Pea aphid, *Illinoia pisi* (Kaltenbach) (see Figs. 298 and 299)
Rose aphid, *Macrosiphum rosæ* Linné (Fig. 480)
Corn root aphid, *Anuraphis maidi-radicis* (Forbes) (see Fig. 203)

Control Measures.—Aphids may be readily controlled under greenhouse conditions by fumigation, spraying, or dusting. During the last 2 years, it has been found possible to control most greenhouse aphids by light applications of calcium-cyanide dust, greenhouse grade, applied to the walks of the greenhouses in the evening (see page 257). In most cases, applications are made at the rate of ¼ ounce of calcium cyanide

dust to each 1,000 cubic feet of space in the greenhouse. Such applications will cause burning on a very few of the more tender plants; but under most conditions the dosage can be increased to ½ ounce per 1,000 cubic feet. The calcium cyanide dust is applied over the walks with a blower or dust gun, or merely sprinkled out from a pail. The house should be closed and not entered for two or three hours after the dust is applied. The hydrocyanic acid gas is given off from the calcium cyanide by contact with the moisture of the air. If the application is made after sundown, the gas will have practically all disappeared from the house by morning, and it will be safe to go into the houses which have been treated with the above dosages.

Aphids may be killed on plants by thorough spraying, using a mixture of ¼ pint of nicotine sulphate to 25 gallons of water, with 1 pound of potash fish-oil soap dissolved in the water. In order to control aphids with this spray, it is necessary to hit their bodies, and a thorough application must consequently be made. A 2 per cent nicotine dust, prepared according to the directions given on page 241 is very effective against most greenhouse aphids, and can often be applied to better advantage than a spray. Fumigation with tobacco extracts is effective in controlling greenhouse aphids. In fumigating with commercial tobacco extracts follow the directions given by the manufacturers.

Greenhouse Whitefly[1]

Importance and Type of Injury.—Plants covered, especially on the under sides, with small, snow-white, four-winged flies, and very small, oval, flat, pale-green nymphs, less than 1/30 inch in length, which suck the sap (Fig. 481). Infested plants are lacking in vigor, wilt, turn yellow and die. The leaves are covered with a coating of glazed, sticky material on which a sooty-colored fungus often grows, completely covering the foliage.

Plants Attacked.—Cucumber, tomato, lettuce, geranium, fuchsia, ageratum, hibiscus, coleus, begonia, solanium, and many other plants.

Life History, Appearance, and Habits.—The female whiteflies deposit their minute yellowish eggs on the under side of the leaves, attaching them by a short slender stem. On hatching, the nymphs are flat and nearly transparent. They settle upon the leaf, near the point where they hatch, and remain in this situation until they become adults. They suck the sap from the leaves, feeding greedily on the plant juices for about 4 weeks. In the course of this time, they pass through four stages. All of the nymphs have fine, long and short, white, waxy threads radiating from their greenish bodies. The average duration of the nymphal period is about 28 to 30 days. The adult whitefly is

[1] *Trialeurodes vaporariorum* Westwood, and others, Order Homoptera, Family Aleyrodidæ.

about $^1/_{25}$ inch in length, very active, four-winged, with a yellowish body, and has the appearance of having been thoroughly dusted with some very fine white material (see Fig. 445). Both males and females fly, and feed, like the nymphs, on the under side of the leaves, living from 30 to 40 days. Under greenhouse conditions, the generations overlap, and all stages of the insect may be found on infested plants at any time.

Control Measures.—Fumigation with hydrocyanic acid gas, or with calcium cyanide, is the best method of controlling the whitefly (p. 254). The dosage used will depend on the plants infested and on the tightness of the greenhouse. One-eighth to one-fourth ounce of sodium cyanide per thousand cubic feet, or the equivalent in calcium cyanide, should be used. Three or four fumigations will usually be necessary before the greenhouse is cleaned of these pests, because some of the nymphs and eggs will be likely to escape the first several fumigations.

Fig. 481.—Greenhouse whitefly, *Trialeurodes vaporariorum* Westwood, adults and nymphs on under side of leaf. Four times natural size. (*From Canadian Dept. Agr. Bull. 7, n. s.*)

If fumigation cannot be practiced, persistent spraying with nicotine oleate, using the stock solution described for the control of mealy bugs (p. 706) at the rate of 1 ounce to 4 gallons of water, will be very effective. Such a spray will have to be applied four or five times before the plants are cleaned up, and it is advisable, on plants with tender foliage, to wash the plants with clear warm water 1 or 2 hours after spraying.

Reference.—Twenty-seventh Rept. Ill. State Entomol. p. 130, 1912.

Greenhouse Thrips[1]

Importance and Type of Injury.—Thrips occur very generally in greenhouses, and several species of the insect are found feeding on various plants. The surface of the leaves becomes whitened and somewhat flecked in appearance. The tips of the leaves wither, curl up, and die. Buds fail to open normally (Fig. 482). The under side of the leaves will be found spotted with small black specks. Where such spots are numerous, the appearance of the foliage becomes marred, and in many cases plants are rendered so unsightly that they cannot be used for decorative purposes.

[1] *Heliothrips hæmorrhoidalis* Bouché, Order Thysanoptera, Family Thripidæ.

Plants Attacked.—Practically all plants found in greenhouses are attacked by thrips. Some of those which suffer most severely are roses, carnations, cucumbers, fuchsias, chrysanthemums, and cinerarias.

Life History, Apperance, and Habits.—There are slight variations in the life history of the species found in greenhouses. A typical life history is about as follows: The female insect deposits her eggs in slits in the leaf, inserting the minute white eggs in the leaf tissues. These eggs hatch in from 5 to 7 days, into active, very pale, white nymphs. The nymphs feed on the tissues of the leaf, rasping the leaf tissue with their mouth stylets and sucking up the sap which flows from the injured area. They pass through four stages in the course of their growth, and in the last stage are inactive for a few days before changing to the adult. The

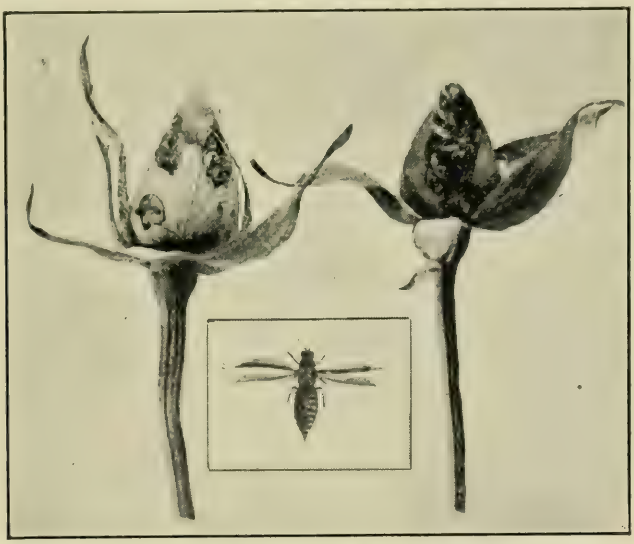


FIG. 482.—The greenhouse thrips, *Heliothrips hæmorrhoidalis* Bouché. Damaged rosebuds and adult thrips; the latter about four times natural size. (*From Canadian Dept. Agr. Bull.* 7 *n. s.*)

adults of different species vary in color, some being yellowish, others nearly black, and others dark brown. They are less than $\frac{1}{10}$ inch long, slender-bodied, and are possessed of three pairs of legs, and four, very slender wings with a fringe of long hairs around their margins (Fig. 482). Under greenhouse conditions, generations follow each other throughout the year, the total time required for each generation being from 20 to 35 days, depending on the climatic conditions and the species of thrips.

Control Measures.—Several fumigations, at weekly intervals, with nicotine as recommended on page 259, are quite effective in the control of thrips. Fumigation with hydrocyanic acid gas also is effective. Spraying with a sweetened arsenical spray, consisting of 2 tablespoonfuls of Paris green, 2 pounds of brown sugar, and 3 gallons of water, is effective if applied to both the upper and the under surfaces of the leaves. This spray cannot be applied to most plants used for foliage decorations, but is useful in some places in the greenhouse where fumigation cannot be

practiced. Spraying with certain derris preparations is effective against these insects.

Other Sucking Bugs

The tarnished plant bug (p. 445), the four-lined plant bug (p. 635), and the garden fleahopper (p. 445) sometimes attack greenhouse plants.

Greenhouse Red Spider[1]

Importance and Type of Injury.—Leaves of plants infested by red spiders present a peculiar appearance. Those lightly infested have pale blotches or spots showing through the leaf. In heavy infestations, the entire leaf appears light in color, dries up, often turning reddish-brown in blotches or around the edge (Fig. 483). Plants generally lose their vigor and die. The under surface of lightly infested leaves will show silken threads spun across them. In heavy infestations, these threads may form a web over the entire plant. The under side of leaves, on close examination, will be found covered with minute, eight-legged mites, showing as tiny, greenish, yellowish, or blackish, moving dots on the leaves.

Plants Attacked.—There are very few plants grown in greenhouses which are not subject to injury by red spiders. Some of the smooth, hard-leaved plants, such as certain palms, are only moderately injured. Some of the worst injured are: cucumbers, tomatoes, carnations, chrysanthemums, melons, sweet peas, snapdragons, violets, and roses.

Life History, Appearance and Habits.—The adult female red spider is an eight-legged, pale-yellow or greenish mite about $1/60$ inch in length (Fig. 483). The male is slightly smaller, being only about $1/80$ inch long. Two dark spots composed of the food contents show through the transparent body wall. The body is oval in outline, and sparsely covered with spines. The mite feeds through sucking mouth parts with which it pierces the epidermis of the leaf. After mating, the female red spiders begin laying eggs at the rate of from 2 to 6 a day, each depositing a total of 70 or more eggs during her lifetime. These eggs are spherical, shiny, very minute; and are attached to the underside of the leaves, usually to the web which the mite spins wherever it goes over the plant. The eggs hatch in from 4 to 5 days into small, crawling young, which closely resemble the adults except that they have only three pairs of legs. The female mites molt three times in the course of their growth, the males molting only twice. A complete generation is produced every 35 to 40 days, but these generations overlap, so that all stages of the mites may be found in the greenhouse at any time.

Control Measures.—Red spiders cause the most damage in greenhouses where plants are grown that require a high temperature and rather dry

[1] *Tetranychus telarius* Linné, Order Acarina, Family Tetranychidæ.

atmosphere. Frequent syringing or spraying of plants with a stream of clear water, applied with sufficient force to tear up the webs of the spiders and knock them from the plants, is one of the most effective methods of control. This treatment cannot be applied to many species of plants, which are injured by frequent watering or develop certain diseases if grown under moist conditions. If houses can be completely cleared of growing plants, red spiders may be cleaned out by heavy

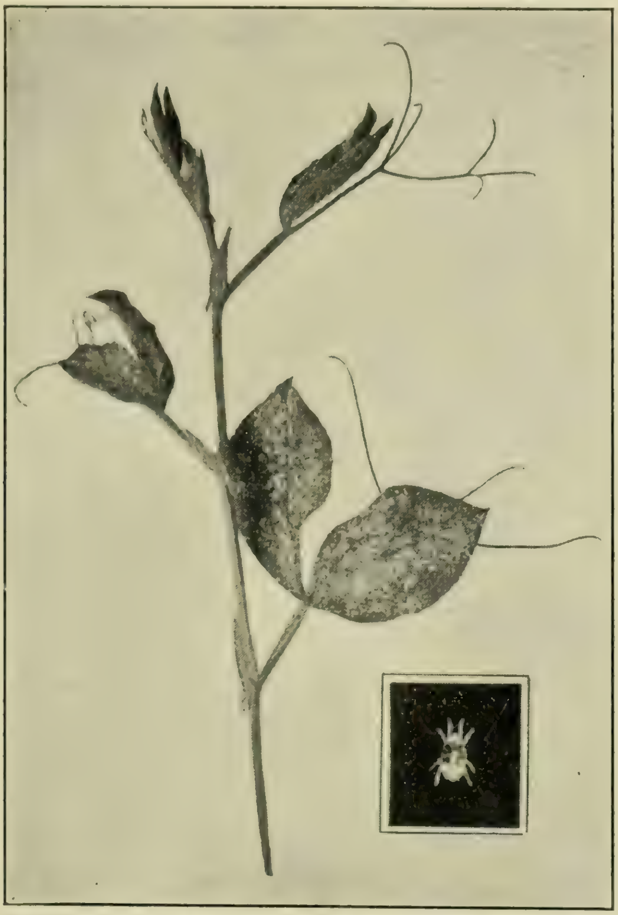


FIG. 483.—Greenhouse red spider, *Tetranychus telarius* Linné. Injury to foliage of sweet pea, about natural size. Adult mite below, about twelve times natural size. (*From Canadian Dept. Agr. Bull.* 7, *n. s.*)

fumigations with sulfur, burning the sulfur at the rate of ½ pound to each 1,000 cubic feet of space. *Such fumigations cannot be given to living plants.* On carnations, the mites may be kept down by spraying the carnations with a very weak solution of dry lime-sulfur 3 pounds to 50 gallons of water. A proprietary spray which is very effective in killing the mites is known as "lemon oil." This should not be confused with oil of lemon, which is an entirely different material. Frequent dusting of the beds and leaves of plants with superfine sulfur is also of value in red-spider control. As the mites survive the winters outdoors and frequently become very abundant outside of the greenhouse, it is highly advisable

to keep down all rank growth of weeds and grasses within the immediate vicinity, as the spiders often breed outside, and later gain access to the greenhouses.

References.—*U. S. Dept. Agr. Farmers' Bull.* 1306, 1923; *Fifteenth Rept. State Entomol. S. Dak.*, 1925.

Greenhouse Leaf Tyer[1]

Importance and Type of Injury.—The under surfaces of the leaves are eaten by slender, pale-green, active caterpillars (Fig. 485). The leaves are sometimes covered with a light web, enclosing several leaves or drawing the parts of a single leaf together.

Fig. 484.—Adult of the greenhouse leaf tyer, *Phlyctænia ferrugalis* Hübner, in resting posture, about twice natural size. (*From Canadian Dept. Agr. Bull.* 7, *n. s.*)

Plants Attacked.—Chrysanthemum, snapdragon, cineraria, aster, sweet pea, ageratum, and many other greenhouse plants, as well as many out-of-door weeds and cultivated crops.

Life History, Appearance, and Habits.—The adult moths (Fig. 484) are of a brownish color, with the front wings crossed by dark wavy lines. The wings expand to about ¾ inch. They remain quiet about the greenhouse most of the day, flying actively at night. When disturbed during the day, they fly with a jerky motion, seeking shelter on the underside of the leaves or other objects after a very short flight. The female moths lay their eggs singly or in overlapping masses, on the undersides of the leaves. These eggs hatch in about 2 weeks into small, slender caterpillars which soon take on a pale green color. When full-grown, the caterpillars are slightly less than ¾ inch long, of a pale-yellow color, with a broad white stripe running lengthwise over the back and a dark-green band in the center of this white stripe. When ready to pupate, the caterpillars usually form a shelter by rolling over the edge of the leaf and fastening it together with threads of silk. Inside this shelter, they spin thin silken cocoons, and then change to the pupal stage. After 10 or 12 days, the adult moths emerge from these cocoons. The length of the entire life cycle is about 40 days.

Control Measures.—Good greenhouse sanitation is one of the most effective ways of preventing attacks of the greenhouse leaf tyer. Fumigation with calcium cyanide, as recommended for the control of greenhouse aphids, is quite effective in killing the adult leaf tyers. Such fumigations, however, kill only the adult stage of the insect. If the plants grown in the greenhouse are sufficiently hardy to withstand a fumigation with this material about once a week until four or five fumigations have been applied, practically all of the leaf tyers can be cleaned out of the houses.

[1] *Phlyctænia ferrugalis* Hübner, Order Lepidoptera, Family Pyralididæ.

Dusting infested plants with a mixture of 1 part arsenate of lead to 4 parts of dusting sulfur, is very effective in killing the young larvæ, if thoroughly applied to the plants with a good dust gun. This dust will

Fig. 485.—Destructive work of the greenhouse leaf tyer. Leaf of marigold at left, showing caterpillars at work; ageratum plant at right, destroyed by the caterpillars. (*From Canadian Dept. Agr. Bull.* 7, *n. s.*)

burn some of the more tender greenhouse plants, so that care must be taken in its application. Fumigation with nicotine, applied as strong as the plants will bear and repeated at weekiy intervals, is also fairly effective as a means of control.

Reference.—Jour. Agr. Research, Vol. 29, No. 3, 1924.

Oblique-banded Leaf Roller[1]

Importance and Type of Injury.—This leaf roller is common in greenhouses. The type of injury is much the same as that of the greenhouse leaf tyer. The pale young larvæ, after hatching from the eggs, live for a time as leaf miners, and then feed for the remainder of their life on the undersides of the leaves. The adult moth is a little over 1 inch across the wings, of a reddish-brown color, with the front wings crossed by three distinct bands of dark brown. The control measures are the same as for the greenhouse leaf tyer.

Florida Fern Caterpillar[2]

Importance and Type of Injury.—Ferns attacked by this insect have the leaflets stripped from the old growth, and the new growth entirely eaten away. Large ferns may be completely stripped of leaves in 1 or 2 days. Ferns are disfigured to such an extent that they are useless for decorative purposes and cannot be sold.

Life History, Appearance, and Habits.—The adult moth is of a general brown color with a rather dark V-shaped patch near the center of the wings. The front wings, as a whole, are variegated. The wings expand about 1 inch. The eggs are laid on the undersides of the leaves, and hatch in from 5 to 7 days into uniformly pale-green larvæ. These larvæ later change to a slightly darker green or to velvety black. There are two wavy white lines down each side of the body, and a central stripe of somewhat darker color. The full-grown larvæ are about 1½ inches in length. These caterpillars feed very actively at night, cutting off and devouring the fern leaves. On becoming full-grown, they work their way into the soil and there spin a cocoon in which they change to reddish-brown pupæ. The pupal stage lasts about 2 weeks. There may be a complete generation of this insect every 7 or 8 weeks.

Control Measures.—Arsenical poisons have not been found particularly effective against this caterpillar. Recent experiments in Canada have shown that dusting ferns with pyrethrum powder, applying the dust twice each week, was very effective in controlling the fern caterpillar. A spray composed of:

Fresh pyrethrum powder	½ pound
Common laundry soap	¼ pound
Water	8 gallons

was also very effective in poisoning larvæ of this insect.

Cutworms[3]

The same cutworms that attack garden and field crops outdoors occur also in greenhouses. The liberal use of the poisoned-bran bait as recommended for the control of cutworms, on page 323, will be found effective in cleaning them out of greenhouse benches or beds.

Corn Earworm and Other Caterpillars

A full description of the corn earworm is given on pages 350 and 490. It frequently happens that the moths when abundant in the fall of the year will enter greenhouses in large numbers and lay their eggs on many of the greenhouse plants, particularly chrysanthemums. The injury caused by young earworms feeding on the chrysanthemum buds is often very severe. Dusting infested chrysanthemums with

[1] *Archips rosaceana* Harris, Order Lepidoptera, Family Pyralididæ.

[2] *Callopistria floridensis* Guenee, Order Lepidoptera, Family Noctuidæ.

[3] Order Lepidoptera, Family Noctuidæ.

calcium arsenate, using the grade of calcium arsenate recommended for cotton dusting, has proved very effective in the control of these insects. They may also be killed by dusting the plants with calcium fluosilicate. There is a slight danger of burning with the calcium arsenate, but practically none with the calcium fluosilicate. The European corn borer, (p. 333), the cabbage looper (p. 498), and the yellow woolly bear (p. 441) also sometimes attack greenhouse plants.

Strawberry Rootworm[1]

Importance and Type of Injury.—Roses attacked by this beetle have the leaves riddled with small holes, often to such an extent that they appear to have been peppered with shot. The bark is eaten from the new growth, and the eyes of the buds are frequently eaten out. An examination of the roots will show small, curved-bodied, whitish grubs eating off the small feeding roots and scoring the bark of the larger roots (see also p. 643 and Fig. 437).

Plants Attacked.—Rose, raspberry, blackberry, grape, oats, rye, peach, apple, walnut, butternut, wild crab, mountain ash, and several others.

Life History, Appearance and Habits.—The females of the strawberry rootworm are about ⅛ inch long and two-thirds as wide (Fig. 438). Most of the beetles are brownish, but some are brownish-black, usually with four black spots on the wing covers. They lay their eggs in bunches of from 4 to 15 on dead leaves on the surface of the benches. The eggs hatch in from 10 days to 2 weeks, and the small grubs work their way into the soil, and begin feeding on the rootlets. They become full-grown in from 35 to 60 days. They then change in the soil into the soft white pupal stage in which they remain for about 2 weeks, emerging as adults at the end of this period. There are several generations a year under greenhouse conditions. While this insect has been known for a number of years as a pest of strawberries, its injury to greenhouse plants has been comparatively recent. Both sexes of the insect are found out-of-doors, but only females have been found in the greenhouse.

Control Measures.—Spraying the rose plants with calcium arsenate, at the rate of 4 pounds to 50 gallons of water, is a fairly effective means of control. Such a spray should be applied shortly after the plants are cut back, as it is at this time that they suffer the worst injury from the beetle.

During the resting period of the rose plants in the summer, most of the beetles in the greenhouse may be killed by heavy fumigations with hydrocyanic acid gas, using the gas as strong as the plants will permit, or about 2 ounces of sodium cyanide or the equivalent of calcium cyanide to 1,000 cubic feet for 2 hours. It is also advisable in badly infested houses to cover the soil at this time with a heavy application of finely ground tobacco dust. As the soil will not be watered during the drying-out period of the plants, this layer of dust will remain effective for some time and will kill many of the beetles or young larvæ hatching from the

[1] *Paria canella* Fabricius, Order Coleoptera, Family Chrysomelidæ.

eggs. All dried leaves on the benches should be collected and burned at short intervals.

Reference.—U. S. Dept. Agr. Dept. Bull. 1357, 1926.

Chrysanthemum Midge[1]

Importance and Type of Injury.—Infested plants have the leaves misshapen, in cases of light infestations, with small, somewhat blister-like, cone-shaped galls on the upper surfaces. In severe infestations, the leaves are curled, the flowers are distorted, with crooked stems, and with numerous galls along the stems and leaves (Fig. 486).

Fig. 486.—Injury caused by the chrysanthemum midge, *Diarthronomyia hypogæa* Loew. About natural size. (*From Mich. Agr. Exp. Sta. Spcl. Bull.* 134.)

Plants Attacked.—Chrysanthemums of all varieties.

Distribution.—This insect is a late importation from Europe, having first been found in this country in 1915. It is now generally distributed in greenhouses over the United States and Southern Canada.

Life History, Appearance, and Habits.—The adult insect is a very frail little gnat, about $\frac{1}{14}$ inch in length. The general color of the fore part of the body is reddish orange. The abdomen of the female is reddish to orange, and that of the male, yellowish to orange. The female flies lay very minute, orange-colored eggs on the surface and tips of the new growth of the chrysanthemums. The maggots hatching from these eggs bore their way into the plant tissues. The irritation resulting from their feeding causes the growth of small, cone-shaped galls. On the leaves, these galls are usually on the upper side, but they may occur also along the stems, many galls developing so close together that they form masses or knots on the stems. Inside these galls the maggots develop, reach their full growth, and pupate. On emerging, the empty pupal skin will usually be left protruding from the gall. In nearly all cases, the adult flies emerge after midnight and before morning. The life cycle requires, on the average, about 15 days. There may be five or six generations a year under greenhouse conditions.

[1] *Diarthronomyia hypogæa* Loew, Order Diptera, Family Cecidomyiidæ.

Control Measures.—Nightly fumigation with nicotine for a period of from 30 to 40 days is effective in cleaning up these insects. Such fumigations do not kill any of the larvæ or pupæ within the galls, but will kill the adult flies. For this reason, a fumigation is necessary every 24 hours over a considerable period in order completely to clean out the insects from infested houses.

Spraying with a mixture of:

40 per cent nicotine sulfate	1¼ teaspoonfuls
Soap	1 ounce
Water	1 gallon

has proved very effective in cleaning out infested greenhouses. Sprays should be applied every second day for a period of about 6 weeks. This spray will kill the newly emerging adults, and also destroy all eggs which are wet by it. As the adults emerge at night, the best results will be had if this spray is applied late in the afternoon. On certain varieties, a slight discoloration of the leaves may result from frequent spraying with this solution, but this is usually quickly outgrown.

Reference.—U. S. Dept. Agr. Dept. Bull. 833, 1920.

Rose Midge[1]

Importance and Type of Injury. —Flower buds are distorted, turning brown and dying. Tender growth is sometimes curled and brown, the buds and young shoots failing to develop. An examination of buds will show whitish maggots clustered inside, mainly at the base, or on the upper sides of the tender leaves and leaf petioles. The maggots are about $\frac{1}{20}$ inch in length when full-grown. They are at that time somewhat tinged with red.

Plants Attacked.—Roses.

Life History, Appearance, and Habits.—The adult midge is a very small, two-winged fly, about $\frac{1}{20}$ inch in length, and of a reddish or yellowish-brown color (Fig. 487). They are usually most abundant in greenhouses during the summer and early fall. The females deposit their very minute yellow eggs, inserting them into the buds usually just behind the sepals of the flower buds, or in the unfolding leaves. The whitish maggots issuing from these eggs feed on the tender tissue of the new growth and inside the buds, becoming mature in 5 or 6 days. They then drop to the ground, where they spin a cocoon in which the pupal stage is passed. The length of the life cycle varies with the temperature of the house; but, under favorable conditions, a complete generation may appear every 20 days. Usually the winter is passed in cocoons in the soil.

Control Measures.—Probably the cheapest and most effective control for this insect is to cover the surface of the beds with finely-ground

[1] *Dasyneura rhodophaga* Coquillett, Order Diptera, Family Cecidomyiidæ.

tobacco dust, putting on a sufficient amount of dust to make a layer 1/4 inch deep over the surface of the beds. This not only kills the full-grown maggots when they drop from the plants, but also kills the pupæ in the cocoons, and has been found entirely effective for cleaning up this insect. In applying the tobacco dust, it is necessary that care be used to make a complete covering over all parts of the beds, and around the stems of the growing roses. In addition to covering the surface of the beds, all dirt walks and soil under the benches should be thoroughly sprayed with a 10 per cent kerosene emulsion.

Fig. 487.—The rose midge, *Dasyneura rhodophaga* Coquillett. Adult female, greatly enlarged, and antenna in detail. (*From Ill. State Nat. Hist. Sur.*)

Where the rose midge has become established in houses, a vigorous campaign should be waged against it, as it is possible for the insect to destroy the entire crop in a short time. Aside from the use of tobacco, all infested buds should be picked off and burned. Fumigation with tobacco every night for 2 or 3 months is fairly effective. Such fumigations kill the adults, but do not injure the other stages of the insect.

Fungus Gnats[1]

Importance and Type of Injury.—Plants are lacking in vigor and leaves turning yellow, without visible injury to any part of the plant above the ground. Roots with small brown scars on the surface, or with small feeding roots and root hairs eaten off. Very small, thread-like, active, white maggots embedded in the root tissue, or working through the soil about the plant. Often injurious to potted plants.

Plants Attacked.—Many species of plants grown in greenhouses.

Life History, Appearance, and Habits.—There are several species of so-called fungus gnats which cause injury to the roots and underground parts of the stems of

[1] Order Diptera, Family Mycetophilidæ.

plants in greenhouses. The adults are all very small, sooty-gray, or nearly black flies or gnats, measuring from $\frac{1}{8}$ to $\frac{1}{10}$ inch in length. These flies deposit their eggs in clusters of 2 to 30 or more in the soil, each female laying from 100 to 200 eggs. The eggs are only about $\frac{1}{100}$ inch in length, almost too small to be seen, although the egg clusters may be readily found. After about 6 days, small legless maggots with black heads and nearly transparent bodies, hatch and begin working their way through the soil. The maggots feed for 5 to 7 days, and on becoming full-grown are about $\frac{1}{4}$ inch in length. They form a flimsy cocoon in the ground and there pupate. In 5 or 6 days, the adult flies emerge from the cocoons and work their way to the surface of the soil. They live for about 1 week, while they mate and lay eggs for another generation.

Control Measures.—Thoroughly drenching the soil with a solution of mercuric bichloride, or corrosive sublimate, used at the rate of 1 ounce dissolved in 8 gallons of water, is very effective in killing these maggots, and will not cause injury to any but the most tender-rooted plants. Mercuric bichloride is a deadly poison, and care must be used in handling it. The solution should not be allowed to come in contact with the bare skin. It also has a very corroding effect on metals, and should be used in glass or wooden containers. Allowing the soil to dry to as great a degree as possible without injury to the plants also is effective in killing many of the maggots; but it is seldom that all can be cleaned out by this method.

FIG. 488.—Narcissus bulbs infested with larvæ of the narcissus bulb fly, *Merodon equestris* Fabricius, the bulb on the left opened to show the larva and its work; about natural size. (*From Canadian Dept. Agr. Bull.* 7, *n. s.*)

NARCISSUS BULB FLY[1]

Importance and Type of Injury.—Bulbs of narcissus and other plants fail to grow. The bulbs become soft and the outer scales of the bulbs often have brown scars upon them. An examination of the bulbs will show a large whitish or yellowish-white maggot inside the bulb, feeding on the plant tissue (Fig. 488).

[1] *Merodon equestris* Fabricius, Order Diptera, Family Syrphidæ.

Plants Attacked.—Narcissus, hyacinth, amaryllis, galtonia, and several others.

Distribution.—The insect is of European origin, and is now well established throughout the western part of Canada. It has frequently been found in shipments of foreign bulbs, and has been reported from many points in the United States.

Life History, Appearance, and Habits.—The adult of the narcissus bulb fly is a shiny, yellow-and-black, hairy fly, about the size of a small bumble bee, which it somewhat resembles in appearance. The eggs are laid in the base of the leaves or in the necks of bulbs. The young maggots hatching from them bore into the bulb and rasp or tear apart the plant tissues by means of their strong, somewhat hooked mouth parts. The maggots are whitish to yellowish-white in color, thick and fat in appearance, and reach a length of ¾ inch. The puparia are formed in the bulb or in the soil. There is probably not more than one generation a year.

Control Measures.—Treating bulbs with hot water has been found one of the most effective methods of controlling this insect. The bulbs should be submerged in water held at a temperature of 110 to 111.5° F. for 2½ hours. When bulbs are taken up from the field, the infested ones can usually be sorted out by their lighter weight, softer condition, or partly decayed appearance. Bulbs showing indications of heavy infestation should be destroyed by burning, and the remainder of the lot sterilized in hot water.

References.—*Va. Truck Exper. Sta. Bull.* 60, 1927. *Jour. Econ. Entomol.* Vol. 21, pp. 352–357, 1928.

Fig. 489.—The lesser bulb fly; *Eumerus strigatus* Fallen; bulb showing larvæ, somewhat reduced. (*From U. S. D. A. Farmers' Bull.* 1362.)

Lesser Bulb Fly[1]

Importance and Type of Injury.—The injury closely resembles that of the narcissus bulb fly. The maggots are grayish or yellowish gray, and the body is markedly wrinkled (Fig. 489). Many maggots will often be found in a single bulb. They reach a length of about ½ inch.

Plants Attacked.—Narcissus, hyacinth, amaryllis, onion, iris, shallot, and several other plants.

[1] *Eumerus strigatus* Fallen, Order Diptera, Family Syrphidæ.

Distribution.—The distribution of this insect is about the same as that of the narcissus bulb fly. It is probably already established out-of-doors in some points in the United States.

Life History, Appearance, and Habits.—The adult fly is of a blackish-green color, 1/3 inch long, with the body nearly bare of hairs, but with several white lunate markings on the sides of the abdomen. It somewhat resembles a small wasp. The general life history is the same as that of the narcissus bulb fly, but there are probably two generations a year.

Control Measures.—The control measures are the same as those suggested for the narcissus bulb fly.

White Grubs

Importance and Type of Injury.—White grubs of the same species as those attacking the roots of plants outdoors (see Corn Insects p. 306), occasionally occur in numbers in greenhouses. They may be the grubs of the ordinary June beetles, or those of several other beetles, particularly of the genus *Ochrosidia* or the Japanese beetle (p. 605) or cyclamen weevil.[1] In most cases, the insects are brought into the greenhouse with infested soil. In a few cases, particularly with *Ochrosidia*, the adult beetles may gain access to the greenhouses at night, during the period of the year when the insects are abundant, and lay their eggs in the soil of pots or benches. The length of the life cycle under greenhouse conditions has never been carefully worked out. With the last-mentioned species, however, it does not occupy more than one year.

Control Measures.—The best method of controlling white grubs in greenhouse soils is to sterilize the soil with steam or carbon bisulfide (see under nematodes, p. 729). A careful inspection should be made of all soil brought into the greenhouse, to make sure that it does not contain large numbers of these insects. The adult beetles may be kept out of the greenhouses by screening.

Other Greenhouse Beetles

Wireworms (see p. 303) gain access to greenhouse soils in the same way as white grubs. The treatment for these insects under greenhouse conditions is the same. The cyclamen weevil[1] and the Japanese beetle (see p. 605) are greenhouse pests in areas where they occur.

Bulb Mite[2]

Importance and Type of Injury.—Bulbs of various species of plants rot and fail to produce growth (Fig. 490). Plants grown from bulbs turn yellow and present a general sickly appearance. The leaves of such plants are stunted and distorted, and the plants will generally fail to produce flowers, or will produce only misshapen ones. Very small, whitish, six- or eight-legged mites may be found in large numbers sheltering behind or boring into the bud scales.

Plants Attacked.—These mites attack practically all classes of bulbs, some of the more commonly infested being narcissus, tulip, lilac, and hyacinth.

[1] *Brachyrhinus sulcatus* (Fabricius), Order Coleoptera, Family Curculionidæ.

[2] *Rhizoglyphus hyacinthi* Boisduval, Order Acarina, Family Tyroglyphidæ.

Distribution.—These creatures are of European origin, but have been now generally distributed throughout the United States and Canada in shipments of bulbs from Europe, Japan, and the Bermuda Islands.

Life History, Appearance, and Habits.—Infested bulbs will contain practically all stages of the bulb mite. These mites are very small,

Fig. 490.—The bulb mite, *Rhizoglyphus hyacinthi* Boisduval; mites working in a rotten bulb, and their eggs; enlarged about eight times. (*From Conn. Agr Exp. Sta. Bull.* 225.)

whitish, barely visible to the naked eye (Fig. 490). The eggs are laid behind the bud scales and soon hatch into the six-legged nymphs. After molting, these nymphs change to the eight-legged form, and during this second instar of their life are most destructive to the bulbs. After a second molt they become adults and begin to reproduce. The mites apparently prefer healthy bulbs and migrate through the soil from the decaying bulbs to the more attractive food. They are readily trans-

ported from place to place in bulb shipments. The life of the female bulb mite is about 1 month, while that of the male is less. Each female deposits from 50 to over 100 eggs.

Control Measures.—All bulbs found infested by the mites should be destroyed by burning at the time of digging, or when the bulbs are planted, either in the field or in the greenhouse. Infested bulbs can be recognized by their soft, mushy condition. They may be dipped in a solution of 40 per cent nicotine sulphate, using 1 part of the nicotine to 400 parts of water. If bulbs are submerged for 3 hours in water heated to 110° F., practically all the mites will be killed. Sound, healthy bulbs in which the root growth has not started, will not be injured by this treatment.

Reference.—Conn. Agr. Exp. Sta. Bull. 225, p. 126, 1921.

FIG. 491.—Cyclamen blooms destroyed by the cyclamen mite, *Tarsonemus pallidus* Banks; healthy bloom at right. About natural size. (*From Canadian Dept. Agr. Bull. 7, n. s.*)

CYCLAMEN MITE[1]

Importance and Type of Injury.—Infested plants have the leaves distorted, with the buds failing to open or with small distorted flowers, presenting a streaked and blotchy appearance (Fig. 491). The foliage shows purplish areas. Small, white or pale-brown mites, with six or eight legs, work about the base of the plants or in the buds or the injured areas on the leaves.

Plants Attacked.—Cyclamen is injured more than any other plant. This mite is also recorded as a pest of snapdragon, geranium, chrysanthemum, larkspur, begonia, and fuchsia.

[1] *Tarsonemus pallidus* Banks, Order Acarina, Family Tarsonemidæ.

Distribution. Like the preceding, it is an imported species. It was first noticed in New York in 1898, and in Canada in 1908. It is now generally distributed in greenhouses throughout the country.

Life History, Appearance, and Habits.—The adult mites are pale, shiny, brown creatures with four pairs of legs. The immature forms are paler in color, glassy-looking, and have only three pairs of legs. The eggs are laid about the bases of cyclamen plants, and also in the injured areas in the leaves. They are only about $\frac{1}{50}$ inch long, and can barely be seen with the naked eye. All stages of the mites will be found on the foliage of infested plants, usually in greatest numbers about the base of the plants and the flowers or buds.

Control Measures.—Spraying with weak solutions of oil emulsion (see p. 250), using a neutral white oil of about 40 viscosity, at a strength of 1 per cent, has given excellent control of these mites in experimental work in Illinois greenhouses. Thorough spraying with a 40 per cent nicotine sulfate, used in the following dilutions, has been recommended as being very effective:

Nicotine sulfate	1 fluid ounce
Soap	4 avoirdupois ounces
Water	4 gallons

This solution will have to be applied very thoroughly, making four or five applications at intervals of about 1 week.

Sowbugs[1] or Pillbugs[2]

Importance and Type of Injury.—These creatures are not insects but are more closely related to crayfish. They frequently cause some damage in greenhouses. The plants infested show feeding about the roots, and on the tender portions of the stems near the ground. Light gray to slate-colored, fat-bodied and distinctly segmented creatures, with seven pairs of legs, and up to $\frac{1}{2}$ inch long, will be found hiding about the bases of plants or under clods or bits of manure on the surface of the benches (Fig. 492).

Plants Attacked.—Roots and tender growth of nearly all greenhouse plants are attacked.

Life History, Appearance, and Habits.—These creatures reproduce by means of eggs which are retained in the marsupium of the female for about 2 months. Young sowbugs, on hatching, do not leave the marsupium of the female for some time. The young are similar to adults except in size. About 1 year is required for the young bugs to reach full growth. All stages of the bugs will be found in infested greenhouses at the same time.

[1] *Porcellio lævis* Koch, and others, Class Crustacea, Order Isopoda, Family Oniscidæ.

[2] *Armadillidium vulgare* (Latrielle), Class Crustacea, Order Isopoda, Family Armadillididæ.

Control Measures.—One of the best methods of eliminating sowbugs is to poison them, using a poison bran mash made of:

Dry bran	1 peck
Paris green	1/4 pound
Syrup	1 pint
Water	4 quarts

The ingredients should be very thoroughly mixed together, and the bran placed over the benches in small piles, about a handful in a place. Many florists poison the bugs by the use of a mixture of 1 part Paris green to 9 parts sugar. This is either sprinkled over the benches or placed in small piles under clods, bits of manure, or boards, where the sowbugs congregate.

FIG. 492.—Sowbugs feeding in manure. About natural size. (*From Canadian Dept. Agr. Bull.* 7, *n. s.*)

MILLIPEDES[1]

Importance and Type of Injury.—Young shoots of plants are chewed and the tender parts of the stem have areas eaten out of the bark. Seedlings are sometimes cut off. Infested houses have many, long, slender, hard-shelled, very active, crawling creatures (Fig. 280) with two pairs of legs on nearly every segment, hiding under clods on the benches, or scuttling about among the plants.

Plants Attacked.—Many different species of greenhouse plants. However, the main food of these creatures is decaying vegetable matter, particularly manure, used for fertilizing in greenhouse benches.

Life History, Appearance, and Habits.—The eggs are laid either in the soil or on the surface. They are deposited in clusters containing 100 or more. Each female deposits about 300. The eggs are covered with a somewhat sticky material and are nearly translucent when first laid. They hatch in about 3 weeks, giving rise to young millipedes, which differ from the adult only in size, in number of segments on the body, and in having at first only three pairs of legs. They grow slowly, gradually assuming the adult form. There is probably one generation each year.

Control Measures.—The poison-bran bait recommended for sowbugs is quite effective against these creatures. Thoroughly drenching the soil with a solution of

[1] *Orthomorpha gracilis* Koch and others, Class Diplopoda.

mercuric bichloride, at the rate of 1 ounce to 8 or 10 gallons of water, can be used with good results. For small amounts, use the mercuric bichloride at the rate of one 2-grain tablet to 1 pint of water. This poison should be mixed in glass or wooden vessels, and should not be allowed to come in contact with the bare skin.

SLUGS[1]

Importance and Type of Injury.—The foliage of plants, particularly in the damper parts of greenhouses, is frequently fed upon and injured by grayish, or grayish-brown, slimy, legless, soft-bodied creatures, from ½ to 4 inches in length (Fig. 493). A shiny trail, composed of a sticky, viscid secretion given off from the body of the slug, will mark the course of its travels over benches and plants.

Plants Attacked.—Many kinds of plants are attacked, particularly coleus, cineraria, geranium, marigold, and snapdragon.

Life History, Appearance, and Habits.—The eggs are laid in masses, in damp places about the greenhouse benches, underneath boards and flower pots, or in the soil. They are held together by a sticky secretion which turns yellow before the eggs hatch.

FIG. 493.—A slug, enlarged. (*From Canadian Dept. Agr. Bull. 7 n. s.*)

In about 1 month the eggs give rise to very small young, which closely resemble the adult slugs except in size. They develop slowly, and probably live for a year or more.

Control Measures.—Trapping and hand picking are quite effective under greenhouse conditions. For this purpose, bits of boards or several handfuls of plant refuse may be piled about the benches in the damper parts of the greenhouses where the slugs congregate in greatest numbers. If these piles are lifted each morning, and the slugs picked from under them and killed, they can be kept down to a point where little damage will occur except in cases of very heavy infestations. Sprinkling the surface of the heavily infested beds with hydrated lime is also quite effective in killing the slugs; but care will have to be used that the lime is not applied to growing plants, or injury is almost sure to result. Spraying the soil with a solution of mercuric bichloride, as recommended for the control of millipedes and sowbugs, is effective also in controlling slugs.

NEMATODES OR EEL WORMS[2]

Importance and Type of Injury.—Plants infested by nematodes will present a weakened, sickly appearance, without visible injury to the stem or any part of the plant above ground. An examination of the roots will show numerous knots or galls; or, in cases of severe infestation, practically all roots will have a swollen, gouty appearance (Fig. 494).

Plants Attacked.—Four or five hundred different kinds of plants are known to be attacked by nematodes, including practically all plants grown

[1] Class Gastropoda, Order Pulmonata, Family Limacidæ.

[2] *Heterodera radicicola,* Class Nematoda, Family Anguillulidæ.

in greenhouses in the United States. They are particularly a pest of tomatoes and cucumbers, and also very bad on cyclamen.

Control Measures.—The best method of controlling these creatures is to use soil which is known to be free from infestation. If nematodes have gained access to greenhouse benches, it will be necessary to sterilize the soil, between crops, in order to keep down injury. Probably the most effective method of soil sterilization is by steam. Gibson gives the following directions for the use of this method.

Fig. 494.—Roots of a tomato plant, showing enlargements caused by a heavy infestation of eel worms. (*From Ill. State Nat. Hist. Sur.*)

The Pipe Method.—In this method the steam is applied by means of a set of 1¼ inch or 1½ inch pipes, perforated with holes ⅛ to ¼ inch in diameter, and about 1 foot apart. The number and length of the pipes should conform to the boiler capacity and length of beds. According to Selby and Humbert,[1] the perforated pipes should not be more than 40 feet in length, nor exceed seven or eight in number. With medium boiler capacity, say 50 to 60 horsepower, pipes 30 feet in length are most serviceable. The pipes should be about 16 inches apart and should be connected with a 2-inch crosshead by means of T-connections.

In using this system, the pipes are buried at a depth of about 6 inches, care being taken to see that they lie level. The soil is then levelled and covered with canvas or sacking to check the escape of steam.

[1] *Ohio Agr. Exp. Sta., Circ.* 151, 1915.

Potatoes may be used to determine the duration of the treatment. The potatoes should be placed near the surface and treatment stopped when they are well cooked.

Steam sterilization not only eradicates nematodes, but it also rids the soil of all insect life; of pests such as sowbugs; of injurious fungi such as those which cause damping-off, lettuce drop, and Rhizoctonia; and of weed seeds. It also has the advantage of improving the soil conditions, and for this reason it is said that sterilized soil requires less fertilizer than untreated soil.

Where steam sterilization cannot be used, heavy dosages of carbon bisulfide will give some relief, but this has usually not been found as effective as steam sterilization.

Miscellaneous Greenhouse Pests

Ants (p. 734), earthworms, and termites (p. 739) sometimes infest the soil of greenhouses, and the latter are often destructive to the woodwork.

CHAPTER XXI

HOUSEHOLD INSECTS, AND PESTS OF STORED GRAINS, SEEDS, AND CEREAL PRODUCTS

No other insects cause so much personal annoyance and embarrassment as those that frequent our dwellings. They attempt, often successfully, to appropriate our food and clothing to their use, and sometimes even make themselves at home on our persons. Most of these insects may be cheaply and easily controlled, if the right method is employed.

A large number of insects, including many species of beetles, moths, and mites, attack grain and grain products in farmers' bins, elevators, mills, warehouses, retail stores, and the home. The damage done in this way is estimated to exceed $200,000,000 yearly. It is impossible to treat all of these insects in this publication. The more important insects are mentioned, and some of the points of their life history are given.

As the method of control is much the same for all of the insects of stored grains and seeds, no attempt is made to give a separate control for each species, but the general measures for controlling these insects are given near the end of the chapter, pages 761 to 763.

Many of the best publications on these insects deal in a general way with the many species attacking this class of products, and, as some of these publications contain references or short bibliographies, no special references are given for some of the species. Some of the publications dealing with this class of insects are:

U. S. Dept. Agr. Div. Ent. Bull. 4, n. s., rev. 1902; *Kan. Agr. Exp. Sta. Bull.* 189, 1913; *Ill. Agr. Exp. Sta. Bull.* 156, 1912; *Minn. Agr. Exp. Sta. Bull.* 198, 1921; *U. S. Dept. Agr. Dept. Bull.* 872, 1920; *U. S. Dept. Agr. Farmers' Bull.* 1029, 1919; *U. S. Dept. Agr. Farmers' Bull.* 1260, 1922; *U. S. Dept. Agr. Farmers' Bull.* 1275, 1922; *U. S. Dept. Agr. Farmers' Bull.* 1483, 1926; *U. S. Dept. Agr. Dept. Bull.* 1428, 1926; *U. S. Dept. Agr. Dept. Bull.* 1393, 1926. HERRICK, "Insects Injurious to the Household" The Macmillan Company, 1921.

KEY TO INSECTS INFESTING THE HOUSEHOLD, AND STORED GRAIN, SEEDS, AND GRAIN PRODUCTS

A. Ant-like insects crawling openly in the house and getting into foods:

1. Small to very small, active, reddish or brownish, wingless insects, from 1/16 to 1/6 inch long, with a slender waist between thorax and abdomen, run about hurriedly over the floors or shelves of pantries and kitchens and feed upon sweets or, in some cases, on meats and fats. *Corn field ant, Pharaoh's ant* and many others, page 734.

2. Medium-sized to small, black, active, wingless insects, from 3/8 to 1/2 inch long, with a slender waist between thorax and abdomen, feeding on sweets and other food substances, sometimes emerging from cracks in the timbers of houses, or other wooden parts of the building. *Carpenter ant* or *large black ant*, page 734.

3. In the southern and southwestern parts of the United States small, very dark, uniform brown, rather slender-bodied ants, about 1/10 inch long, with long antennæ, a one-segmented pedicel, and no odor when crushed, swarm into houses and over trees, especially citrus. These ants feed on nearly all kinds of human food, including sweets, meats, and fats. *Argentine ant*, page 738.

B. Whitish, ant-like insects working in wood and wood products:

1. Large numbers of slender, dark-brown, winged insects, without a slender waist, emerge from cracks in floors or walls or from holes eaten through the woodwork of buildings. Small, whitish, brown-headed, soft-bodied, wingless insects feed and tunnel in the woodwork of buildings, particularly on timbers that come in contact with the ground. Injured wood is almost completely eaten, except an outer shell. Sometimes cement-like tubes are constructed over brick or stone foundations, leading to the woodwork. *Termites* or *white ants*, page 739.

C. Insects running very swiftly about the house in dark places or at night: rarely found in foods:

1. Slender, pale brown creatures, up to 2 inches in length, with many extremely long legs, scurry rapidly over walls or floors when lights are suddenly turned on. Do not feed on stored foods or fabrics. *House centipede*, page 741.

2. Dark-brown, light-brown or black, shiny, flat-bodied, long-legged insects, the smaller ones without wings, the larger ones winged, feeding on the binding of books, the sizing of papers, and foods of all kinds. The insects are seldom seen in the daytime. A noticeably, sweetish, sickening odor where these insects are present in numbers. *Cockroaches*, page 742.

3. Small, wingless, grayish-white to brownish, carrot-shaped, glistening insects, up to 1/2 inch in length, with slender feelers projecting from the head and from the tail, run rapidly over books, walls, and papers and feed on the binding of books, wall paper, or food stuffs. *Silverfish*, page 744.

D. Insects feeding in tobacco, drugs, the silk upholstery of furniture, leather, etc.:

1. Cigars, cigarettes, and package tobaccos, with small, white, very hairy grubs, and very small, light-brown beetles (1/16 inch long), with hairy, but not striated wings, eat holes through the tobacco or feed in numbers within the packages. Upholstered furniture, with numerous holes, eaten through the covering by these grubs or beetles. *Tobacco beetle*, page 744.

2. Small, white, curved grubs, similar to *D*, 1, but not hairy; and small, rather narrow-oval, reddish brown beetles with striated wings, mine and tunnel through packages of drugs, vegetable poisons, foods, leather, and a great variety of other substances, which they eat. *Drug-store beetle*, page 745.

E. Insects destroying clothing, fabrics, furs, and other animal products:

1. Rugs or carpets with holes eaten in them, or stuffed animals, birds, and insects being fed upon by small, dark-brown, very hairy larvæ about 1/4 inch in length. Small brown-and-gray, or black, beetles, sometimes flecked with red, crawling over infested materials. Beetles oval in outline, about 1/8 inch long. *Carpet beetles, or buffalo beetles, and museum pests*, page 746.

2. Wool or silk clothing, feathers, and other animal products with many silken cases or webs on the surface, containing small whitish worms. Fabrics with numerous holes eaten through them. Small, buff-colored moths, about 1/8 inch long, running rapidly over the surface of fabrics when exposed to light, or flying aimlessly about in closets. *Clothes moths*, page 748.

F. Insects eating in meats, cheese and other foods:

1. Very hairy, brown larvæ, somewhat resembling *E*, 1, but with two, short, curved hooks on the last segment, feed on meats, particularly dried or smoked meats, other food products, feathers, skins, etc. Dark-brown beetles, about ⅓ inch long, with a pale yellow band across the middle of the body, crawling about on the surface of food materials where larvæ are feeding. *Larder beetle*, page 750.

2. Insects similar to *F*, 1, feeding in meats, hides, tallow, and other animal matter. The beetles black above whitish beneath and from ¼ to ⅓ inch long. *Hide beetle, Dermestes vulpinus* Fabricius.

3. Cheese and smoked meats with small yellowish maggots crawling over the surface or through the cheese. These maggots sometimes jump or hop for some distance, by suddenly bending and then straightening their bodies. *Cheese skipper*, page 751.

4. Cheese, hams, cereals, and other food products become musty and are found on close examination to be swarming with tiny, whitish, eight-legged mites not over 1/32 inch long. *Cheese mites, ham mites*, and *flour mites*, page 752.

G. Insects attacking stored grains and grain products:

(*a*) *The parents are hard-shelled beetles: the larvæ do not have prolegs and spin no silk.*

1. Dark-brown, snout beetles, up to ⅙ inch in length, crawling over and through grain products held in storage. Grain heats and becomes moist, sometimes matted together because of sprouting. Individual grains contain white, fat-bodied, legless, white grubs. *Granary weevil*, or *rice weevil*, page 753.

2. Small, dark red, narrow-bodied beetles, about ⅙ inch in length, running rapidly over the surface of grains; often found in flour, meal, breakfast foods, and other food products. Small, brownish-white, six-legged larvæ, about ⅙ inch long, feeding in and on the grain. *Confused flour beetle*, and *rust-red flour beetle*, page 754.

3. Insects similar to *G* 2, but more slender, flatter, and somewhat darker in color, feeding on dried fruits, grain, and grain products, nuts, seeds, and many other foods. Each side of the thorax shows six, fine, saw-tooth-like projections, when examined under a lens. Larvæ with bodies very slender, nearly bare of hairs, somewhat depressed. *Saw-toothed grain beetle*, page 755.

4. Very small dark-brown beetles with rather long, prominent antennæ, and slight knobs at front angles of thorax, found in same situations as *G* 3, and particularly in bins of oats and barley. *Foreign grain beetle, Cathartus advena* Waltl.

5. Smooth, shiny-bodied, uniformly brown to yellow worms closely resembling wireworms, feeding in the lower parts of, or beneath grain bins and where the grain is moist. Rather robust, somewhat flattened, black to brown beetles, up to nearly 1 inch in length, in the same situations. *Yellow meal worm* and *dark meal worm*, page 756.

6. Black beetles, somewhat resembling *G* 5, but smaller in size, about ½ inch in length, with the head and prothorax distinctly separated from the rest of the body by a narrow waist. Whitish to grayish-white, soft-bodied larvæ, with black heads and two short black projections from last segment of abdomen, work among grains, particularly where undisturbed for some time. *Cadelle*, page 757.

(*b*) *The parents are delicate winged moths; the larvæ have prolegs and often spin much silk among the grain.*

7. Wheat and corn in storage have small round holes, a little larger than a common pinhead, eaten into the grains. Whitish worms up to nearly ½ inch in length, living and feeding *inside* the kernels. Brownish-gray moths, a little less than ½ inch in length, with a long fringe of hairs on the wings, fly about the bins or cribs, or crawl over the surface of the grain. *Angoumois grain moth*, page 758.

8. Flour in mills, and sometimes in storehouses, webbed and matted together in masses, by small white to pinkish worms up to ⅗ inch in length, which are usually

concealed in their silk tubes. Masses of webbed flour frequently becoming so tightly packed in mill machinery as to prevent the operation of the machines. Gray, black-marked moths, resting on the surface of grain, or flour, in infested mills. *Mediterranean flour moth*, page 759.

9. Flour, grain, and grain products, and especially dried fruits, nuts, nut candies, and other food products, infested by small, whitish to greenish-white worms, up to ½ inch in length. More or less webbing of infested material, but not so much as in *G* 8. Small moths with the basal half of the front wings much lighter in color than the tip, resting on infested material, or flying about over it. *Indian meal moth*, page 760.

H. Insects attacking stored beans and peas, also the developing seeds within pods in the field:

1. Peas in the pod contain white, nearly footless grubs or short, chunky, brownish beetles which feed exclusively inside and show no entrance hole except a small dark dot. Stored peas often show a small round hole where the beetle has emerged. Beetles ⅕ inch long with two black spots on the extreme tip of the abdomen that is exposed beyond the wing covers. Hind femur with a sharp tooth near apex. *Pea weevil*, page 763.

2. Similar to the preceding but occuring chiefly in broad-beans in addition to peas. The adult beetle smaller, without black spots on that part of abdomen exposed beyond the wing covers, and the tooth near apex of femur broader and more blunt than in the pea weevil. *Broad-bean weevil*, page 764.

3. Growing beans and peas attacked in the field and in storage as by the pea weevil, by a smaller, brownish beetle about ⅛ inch long, and by footless white grubs that feed exclusively inside the seeds. Stored beans often show many round holes and fine, powdered frass. Hind femur of beetle has one large and two small teeth near the tip. *Bean weevil*, page 764.

4. Insect and injury similar to the preceding, but prefers cowpeas. Adult with a large dark spot on apex of each wing cover and another pair of spots near the middle of costal margin of wing covers. *Four-spotted bean weevil*, page 765.

5. Insect and injury similar to *H* 3, and *H* 4, but smaller and with two prominent ivory white spots at the middle of hind margin of prothorax. Wing covers with a narrow dark crossband at middle. Male with comb-like antennæ. *Cowpea weevil*, page 765.

A. HOUSEHOLD INSECTS

ANTS[1]

Importance and Type of Injury.—There are few insects which have proved themselves more persistently exasperating to the housekeeper than ants. There are many species of ants which are sometimes found in houses. Everyone is familiar with the fact that when ants have invaded houses, the workers will be found crawling over any food that is to their liking, bits of which they cut off and carry to their nest (Fig. 153). Some species also cause injury by establishing their nests in the sills and woodwork of old houses; but as a rule, they do not attack perfectly sound wood. Other species throw up mounds of earth about the entrance to their nests, disfiguring lawns and walks. Some species obtain a part of their food from the sweet, sticky honeydew given off from the bodies of aphids, scale insects, and mealy bugs and these species may establish and

[1] Many species of Order Hymenoptera, Family Formicidæ.

protect colonies of these insects on plants out-of-doors or in greenhouses or residences.

Food.—The food of ants is even more varied than that of man. To list everything on which they feed would require a volume by itself. They are fond of nearly every kind of human food, and in some parts of the country become a pest from their habit of gathering and storing quantities of grains and seeds in their nests.

Distribution.—As a group, world wide; certain species are more abundant and annoying in some localities.

Life History, Appearance, and Habits.—The appearance of worker ants is well known to anyone who has ever kept his eyes open when out-of-doors. The wingless workers (Fig. 153, *e*) are only one of the forms that occur in the ant colony. There are always winged males and females (*a*, *d*), at least at certain seasons. In some colonies, even the worker caste is divided into two or three forms. Some of these forms, as in the honey ants, have abdomens which can be greatly distended and are used as a sort of jug in which to store honey for the colony. Others, as in some of the seed-gathering ants, have certain castes with enormously enlarged heads and very strong jaws which serve as seed crackers. Ants vary in size from the extremely small, reddish or brownish ants, known as Pharaoh's ants, about $\frac{1}{32}$ inch long, to the large wood-burrowing carpenter ants, workers of which are over $\frac{1}{2}$ inch long. Ants, as a group, can be distinguished from other insects by having one or two wart-like elevations on the slender petiole that separates the thorax from the large part of the abdomen (Fig. 495).

A typical colony of ants consists of from one to several females, or queens, whose duty it is to lay eggs; and thousands of workers. The workers are incompletely developed females and seldom lay eggs. The queens are cared for by the workers and usually remain in the inner chambers of the nest, seldom leaving the nest except at times when the colony may migrate to a new location. From the eggs laid by the females, larvæ or maggots (Fig. 495, *f*) hatch, the majority of which develop into workers after going through the pupal or resting stage, (*b*), either in a cocoon, or without such protection. A certain percentage, however, produce winged males and females, the "kings" and "queens" of the ant colonies. At certain times of the year, varying with the species, these winged males and females leave the nest or swarm. Usually this occurs over a wide area on the same day for any one species. The males mate and soon die. The females fly to situations which are attractive to them as nesting sites, alight, tear off their wings, and make a small nest where they lay a few eggs. After the eggs have hatched, the female feeds and cares for the young larvæ until they have become full-grown. The larvæ of ants are whitish, helpless, maggot-like grubs, without legs and with very small heads. These larvæ produce workers; and, as soon as the

adult workers appear, they start taking care of the queen and her young. From this time forward, the queen confines her activities entirely to egg laying. The queen may live for 12 to 15 years, during which time she will produce many thousands of eggs and may develop many thousands of individuals.

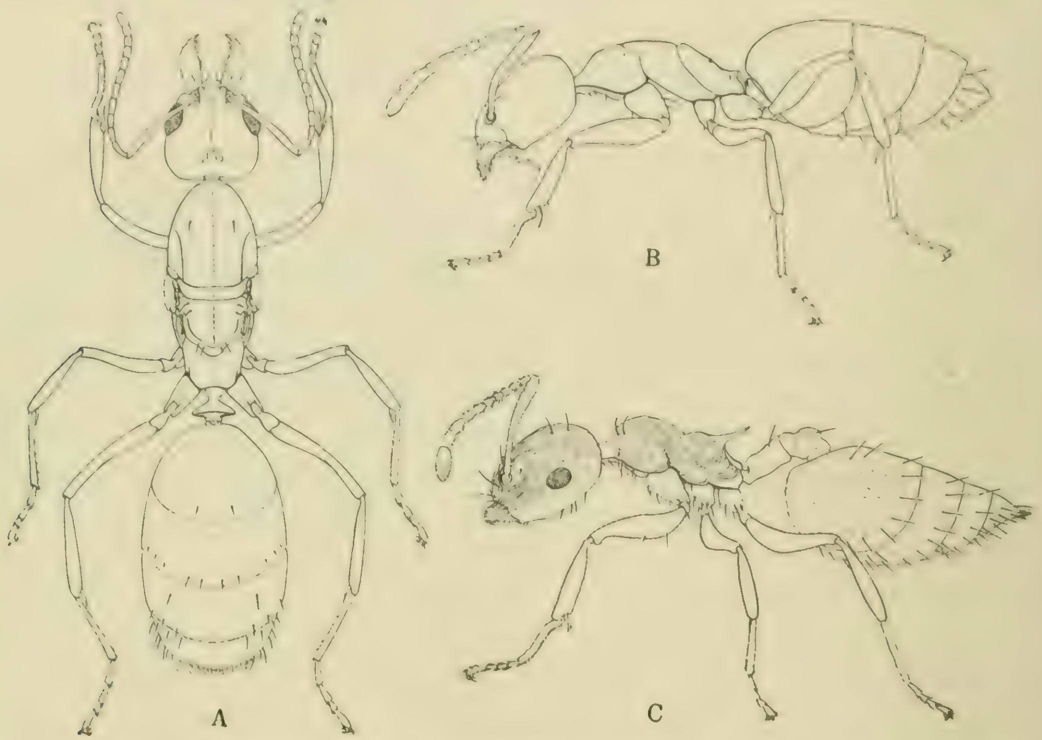


FIG. 495.—Three common and troublesome American ants. *A*, the queen Argentine ant, *Iridomyrmex humilis* Mayr, after discarding her wings. The worst household ant where it occurs in the warmer parts of the United States. Actual size of the queen, about $\frac{1}{5}$ inch long; of the workers, from $\frac{1}{16}$ to $\frac{1}{8}$ inch in length. *B*, Worker of the odorous house ant, *Tapinoma sessile* (Say), the commonest household ant over much of the United States. Length $\frac{1}{12}$ to $\frac{1}{8}$ inch; black; with a pronounced "rotten pineapple" odor when crushed. Note how the top of the abdomen overhangs the nodus of the petiole. *C*, worker of the acrobat ant, *Cremastogaster lineolata* (Say), a shining black species about $\frac{1}{8}$ inch long, that often carries its pointed abdomen turned up over the rest of the body. (*From Woodworth, Calif. Agr. Exp. Sta. Bull.* 207.)

Control Measures.—The most effective method of control will vary with the species. Most ants that feed on sweets can be trapped and killed by dipping small pieces of sponge in syrup and putting these sponges in small tin boxes, such as baking-powder boxes, with several holes punched in the lid with an ice pick or a nail. These boxes can be set about the house at points where the ants are most annoying and left in place until large numbers of ants have congregated in them to feed upon the syrup. The boxes should then be dropped in boiling water, recharged with syrup, and replaced. Persistent use of this method will discourage, and usually clean out, moderate infestations of ants.

One of the best ant poisons is made as follows:

Boil together the following materials for 30 minutes:

Granulated sugar	$1\frac{1}{4}$ pounds
Water	$1\frac{1}{4}$ pints
Tartaric acid (crystallized)	1 gram
Benzoate of soda	1 gram

Dissolve sodium arsenite in hot water in the following proportions:

Sodium arsenite (c. p.)	$\frac{1}{8}$ ounce
Hot water	1 fluid ounce

When the above solutions have cooled, add the second to the first and stir well. Then add $\frac{2}{3}$ pound of strained honey to the resulting syrup and mix thoroughly.

This poison should be put out in the same manner as the syrup used for trapping ants; that is, bits of sponge soaked in the syrup and placed in perforated tin boxes.

For the common outdoor ants which sometimes invade houses in the northern states, the following syrup has been found quite effective as a poison.

Sugar	1 pound
Water	1 pint
Arsenate of soda	125 grains
Honey	1 tablespoonful

Boil the first three ingredients until the arsenate of soda is thoroughly dissolved, and then add the honey.

In using ant poisons, remember that only a small amount of the poison can be included in the syrup. If large amounts of the poison are used, the ants will soon detect it and cease to feed upon the bait. Where only a small amount of the poison is used, the action from it is rather slow, and the workers not only eat the syrup, themselves, but also carry it to their nests and feed it to the queen and young.

Frequently ants can be driven out of buildings by dusting liberal quantities of sodium fluoride in the places where they are causing annoyance.

Most of the ants which invade houses have their nests outside the buildings, usually in the soil. The line of foragers can be usually followed back to the place from which they are coming. If the nest is found, it may be destroyed by liberal applications of carbon bisulfide. To apply this chemical, punch holes in the soil about the nest to a depth of 8 to 12 inches, depending on the size of the nest and the species of ant. Into each of these holes, pour about 1 tablespoonful of carbon bisulfide, and cover the top of the hole with moist earth. Or, if several hills are to be treated in a small area of lawn, a wet blanket or piece of canvas may be used for covering the entire area. In using carbon bisulfide, one must bear in mind that this chemical is inflammable, and when mixed with air highly explosive. All fire must be kept at a distance.

Calcium cyanide, in the dust form, may also be used for destroying ant nests. This is best applied to holes made in the soil in and around

the nest. Several holes should be made 2 or 3 inches apart. The calcium cyanide should be applied with a funnel, a teaspoonful to a hole, putting it only in the bottoms of the holes. If scattered over the surface of the ground, it is likely to kill the grass or other plants. This material, and the gas from it, are very poisonous, and care must be used in handling it.

References.—U. S. Dept. Agr. Farmers' Bull. 740, 1916; Wheeler, "Ants, Their Structure and Behavior," Columbia Univ. Press, 1910.

Argentine Ants[1]

Importance and Type of Injury.—This small ant (Fig. 495, *A*) is the most annoying and destructive ant in the parts of the country where it occurs. It has locally become so abundant in parts of towns and cities as to make neighborhoods undesirable. The injury caused by these ants is of several kinds. They are almost omnivorous, attacking all kinds of food, and are particularly fond of sweets and meats. They also cause serious damage in citrus groves by attacking the blossoms, and by distributing, establishing, and protecting from their natural enemies aphids, certain scales, and mealy bugs.

Food.—Nearly all kinds of human food, and honeydew from insects.

Distribution.—This ant is probably a native of Brazil and was imported into New Orleans about 1891. It has now been spread over most of the southern states as far north as North Carolina, Tennessee, and Arkansas, and also occurs throughout the southern part of California.

Life History, Appearance, and Habits.—The winter is passed in large centralized colonies which become established in the late fall in particularly favorable nesting sites, such as fairly dry manure piles or piles of other decaying vegetable matter. While all stages of the ants may be found at this time of the year, they are relatively inactive except during warm periods. In the spring the worker ants become very active in searching for food, and at this time are especially annoying. The dark-brown worker ants are about $\frac{1}{16}$ to $\frac{1}{8}$ inch in length, with slender bodies and rather long antennæ. The winged queens are nearly $\frac{1}{5}$ inch long. The queens of which there may be several in a central colony, lay eggs which hatch in about 20 to 50 days. The larvæ require about 1 month for their development, and the pupæ 15 days. The life cycle, according to Essig, occupies about 80 days.

Control.—In communities where these ants have become well established, it is necessary that prompt measures be taken for control. The method found most effective in combating these ants is the use of the poison syrup made as described on page 737.

This bait should be exposed in small containers, such as tin boxes containing a bit of sponge which has been wet by the syrup, and having

[1] *Iridomyrmex humilis* Mayr, Order Hymenoptera, Family Formicidæ.

several holes punched in the lids, or paraffined paper bags tacked in trees, with one or two small holes in the top of the bag to permit the ants to have access to the syrup. The persistent use of this syrup, put out in a sufficient number of containers well distributed around infested premises, is very effective in cleaning up this ant. Because it is a very weak poison, several days will elapse before any effect of the syrup is noticeable. The ants may be quickly driven out of infested premises by the use of strong poison syrups, as they detect and are repelled by the poison, but the colonies cannot be eradicated by such strong syrups. The ants do not detect the poison in the weakly poisoned syrup recommended, but carry it to their nests and feed it to the queen and young larvæ. This eventually destroys most of the colony. Organized community action is necessary in order to get any real relief from this pest. (See also page 239.)

References.—*U. S. Dept. Agr. Farmers' Bull.* 1101, 1924; *U. S. Dept. Agr. Dept. Bulls.* 647, 1918; and 965, 1921; *U. S. Dept. Agr. Bur. Entomol. Bull.* 122, 1913.

TERMITES[1]

Importance and Type of Injury.—The presence of termites in dwellings or other buildings is often first indicated by swarms of winged "ants"

FIG. 496.—Termite queen with wings spread; about 6 times natural size. (*From Ill. State Nat. Hist. Sur.*)

(Fig. 496) suddenly appearing inside the buildings, often emerging from holes in the walls, floor, or other parts of the woodwork. All termites differ from true ants in not having a slender waist. Badly infested buildings may suddenly sag, due to the weakening of the frame by the feeding of the termites on the main timbers. Occasionally their presence is indicated by the breaking through of floors or the cutting through of the rugs or floor covering. Brick or cement foundations will have small tunnels constructed over their surfaces, of a clay or cement-like substance. Growing plants may be eaten out.

Food.—The food of termites consists of wood, or wood or animal products.

Distribution.—Termites of various species occur in nearly all the warmer parts of the world, but are much more numerous in the tropics.

[1] Several genera and species of Order Isoptera, Family Termitidæ. *Reticulitermes flavipes* (Kollar) is the commonest species in the eastern United States.

Life History, Appearance, and Habits.—The colonies of termites, or white ants, somewhat resemble those of the true ants in their organization. In the termite colony, however, the male helps to start the nest and remains with the female or queen throughout life. The latter is usually the mother of the entire colony. In some species, more than one royal pair will be found in the colony. There are only three stages in the development of the termites: first the egg; then the immature or nymphal forms; and, finally, the adults, which are always separated into several different castes, such as workers, soldiers, kings, and queens. They do not have larval and pupal stages, as the true ants do. The so-called

FIG. 497.—Termites in their galleries in sill of a house. Slightly enlarged. (*From Ill. State Nat. Hist. Sur.*)

workers and soldiers in the termites consist each of *both* males and females. The workers are the destructive forms which are active in foraging and feeding on wood (Fig. 497). The winged true males and females develop within the colony, and at certain times of the year leave the nest in swarms. Several such swarms may come out from the same nest, usually within short intervals of time. Most of the termite species swarm in the spring. These males and females differ greatly from the soft-bodied, white, wingless workers and soldiers. They (Fig. 496) are black, rather narrow-bodied, and possessed of rather long, very brittle wings, which are broken off near the base when the kings and queens enter the ground after a single pairing flight. After leaving the nest, they separate in pairs and select sites for starting new colonies. As in the case of ants, a colony may endure for many years.

Control Measures.—The controlling of these insects, once they have become established in a building, often means the expenditure of considerable money and labor. If possible, the main colony of the insects should be located and dug up, and the termites killed by thoroughly spraying with kerosene or some other light oil. Passageways that lead over the foundation walls of buildings should be broken and the surface of the wall over which these passages have been running, should be heavily treated with creosote. All woodwork of the buildings, including timbers or parts of the frame work which are badly eaten by the ants, should be replaced with metal or cement, or if this is not advisable, with wood thoroughly treated with creosote. Timbers that have not been seriously damaged, but which are exposed to infestation by termites, should be sprayed with warm creosote, using a compressed-air painting machine or other sprayer that will apply this liquid with considerable force. *To prevent infestation by these pests, great care should be taken to avoid having any woodwork of buildings coming into contact with the ground,* as such points of contact are nearly always the cause of buildings' becoming infested with termites. The insertion of a thin sheet of metal between the foundation and timbers of the house, running all the way around and projecting about an inch on each side, will prevent infestation by these pests.

References.—*U. S. Dept. Agr. Farmers' Bulls.* 759, 1916; and 1472, 1926; *U. S; Dept. Agr. Bur. Ento. Bull.* 94, Part II, 1915; *U. S. Dept. Agr. Dept. Bull.* 333, 1916; *Ill. State Nat. Hist. Sur. Entomol. Ser. Circ.* 11, 1928.

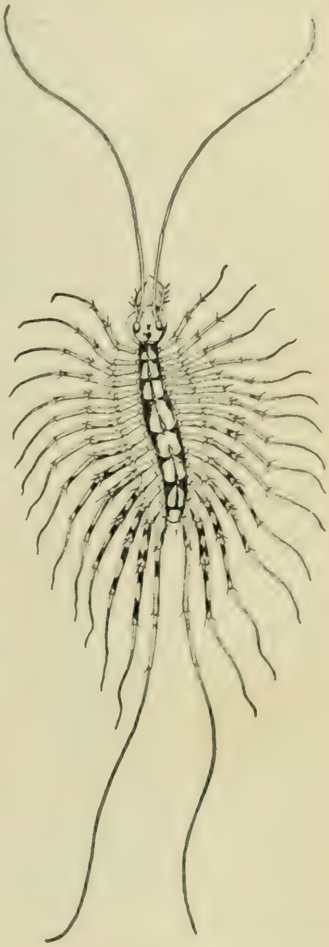


FIG. 498.—House centipede, *Scutigera forceps* (Rafinesque). Adult, natural size. (*From U. S. D. A. Bur. Entomol. Circ.* 48.)

HOUSE CENTIPEDE[1]

This creature, which is frequently encountered about houses, is really beneficial, causing no injury whatever to stored products. It becomes annoying to some people because of its appearance and habit of rushing over the walls or floors, occasionally toward a person, when it is suddenly disturbed by the turning on of lights, or from other causes. There are a few cases on record where the centipede has inflicted a painful bite when handled.

In appearance, these creatures are of a grayish-tan color, with long antennæ and many extremely long legs extending out all around the body (Fig. 498). They move so rapidly that it is often difficult to get an accurate idea of their appearance. When full-grown, they are from 2 to 3 inches in length. Their food consists of small insects, such as roaches, clothes moths, house flies, and others which they may encounter about houses.

[1] *Scutigera forceps* (Rafinesque), Class Chilopoda, Family Scutigeridæ.

Unless they become extremely abundant, they should not be killed. In cases where they do become so numerous as to prove annoying, the liberal use of pyrethrum powder about water pipes, or other damper parts of the house frequented by the centipedes, will be found effective in controlling them. They are killed by fumigation, either with hydrocyanic acid gas or carbon bisulfide, but it is rarely, if ever, necessary to go to this expense for the control of these creatures.

Cockroaches

Importance and Type of Injury.—These brown, brownish-black, or tan, shiny, flat-bodied, foul-smelling insects are well known to almost everyone. They are mainly active at night or in dark basements. Their filthy habits, repulsive appearance, bad odor, and the probability that they may spread diseases make them very objectionable.

Food.—They feed on many kinds of material, often becoming annoying in houses by eating the binding or leaves of books or magazines, the paper covering of boxes, various food products in pantries, kitchens, bakeries, restaurants, and like places, and by fouling with their excreta the material over which they run.

Distribution.—World-wide; especially abundant in the warmer parts of the world.

Life History, Appearance, and Habits.—There are at least three species of roaches which are common in houses in the United States; the small, tan, German roach,[1] about ½ inch long (Fig. 499); the large black Oriental roach,[2] the females of which are nearly wingless and about 1 inch long; and the large, brownish-black American roach,[3] which reaches a length of 1½ inches (Fig. 499, *a*, *b*).

The life histories of all species are much the same. The eggs are laid in pod-like or bean-like cases called *oötheca* (*g*). For a number of days before the eggs are deposited, this pod-like case may be seen protruding from the abdomen of the female (*f*), as she moves about. The small roaches hatching from the eggs have much the same appearance as the adults, except that they lack wings. They develop rather slowly, probably requiring several months, or more, to become full-grown. Cockroaches hide in the cracks of buildings during the daytime, and their abundance is much greater than ordinarily supposed.

Control Measures.—The most effective method of controlling cockroaches, and one that will practically always give relief, is to dust thoroughly all parts of the houses frequented by the insects, with sodium fluoride.[4] This dust should be applied in liberal quantities in the dark corners of closets, at the base of the walls in basements, under sinks, around drain pipes, behind baseboards, upon shelves, or in any cracks

[1] *Blattella germanica* Linné, Order Orthoptera, Family Blattidæ.

[2] *Blatta orientalis* Linné, Order Orthoptera, Family Blattidæ.

[3] *Periplaneta americana* Linné, Order Orthoptera, Family Blattidæ.

[4] Sodium fluoride not to be confused with *sodium chloride*, or common salt.

in the wall, where the cockroaches are likely to hide. If this treatment is persisted in, even the most severe infestations may be entirely cleaned up. The roaches do not feed on the powder, but get it upon their bodies, and in cleaning their feet and legs, take particles of the material into their mouths, and so become poisoned. One should bear in mind that

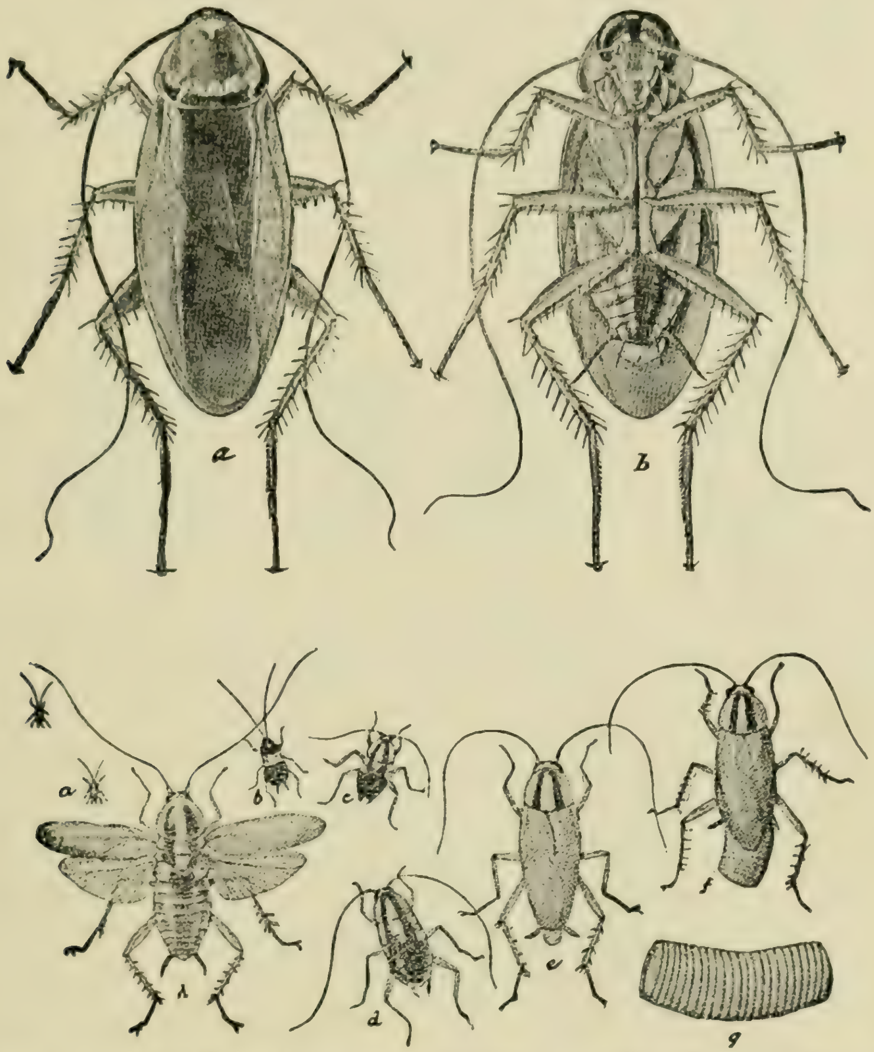


FIG. 499.—Cockroaches. Above the American cockroach, *Paraplaneta americana* Linné: *a*, dorsal view; *b*, ventral view. Below the German cockroach, *Blattella germanica* Linné, adults and young; *f*, female with egg capsule protruding from tip of abdomen; *g*, egg capsule. (*From U. S. D. A.*)

sodium fluoride is poisonous, and it should not be put out where children, or animal pets, will get it in their food.

Even though all roaches have been cleaned out of a house, the house will not remain free long if other houses in the immediate vicinity are infested, as these insects move about quite freely, and actual migrations of the insects from house to house have been noted.

Reference.—U. S. Dept. Agr. Farmers' Bull. 658, 1915.

Silverfish[1]

Importance and Type of Injury.—The bindings of books, papers, cards, boxes and the like have the surface eaten off in irregular patches; the paper on walls is gnawed or the paste largely eaten off where the paper is attached to the walls. Small, whitish or grayish-brown, glistening, carrot-shaped insects, up to $\frac{1}{2}$ inch long (see Fig. 95), scurry rapidly about over shelves and walls on exposure to light.

Food.—These insects feed on a large variety of materials, such as starched clothes, bindings of books, book labels, the sizing of paper, or any papers on which paste or glue has been used.

Distribution.—General throughout the United States and Canada.

Life History, Appearance, and Habits.—The insects reproduce by means of eggs, the young closely resembling the adults except in size. The full-grown insect is wingless, about $\frac{1}{3}$ to $\frac{1}{2}$ inch in length, varying with the species; of a silvery, grayish, or brownish color sometimes faintly spotted. The body tapers very markedly from head to tail, and is covered with thin scales which give it a silvery shiny appearance. Long, slender appendages protrude both from the head and tail. The length of the life cycle will vary with the species, but requires several months in any case.

Control Measures.—This insect may be controlled by liberally dusting pyrethrum powder, or sodium fluoride, about the parts of the houses where they are most abundant. Fresh pyrethrum is somewhat better than the sodium fluoride for the control of this insect.

Silverfish may also be killed by the use of poisoned baits. A bait found to be quite effective by G. J. Spencer (unpublished thesis) consists of sodium fluoride 12 parts, in flour 100 parts by weight. The poison should be thoroughly mixed with the flour and then scattered about in the situations where the silverfish have been noticed.

Reference.—*U. S. Dept. Agr. Farmers' Bull.* 902, 1917.

Tobacco Beetle[2]

Importance and Type of Injury.—This is the most important insect pest of tobacco in factories and cigar stores, and also causes considerable damage to other products. Package and chewing tobaccos, cigars, and cigarettes, have holes eaten through the tobacco (see Fig. 18), and many, small, light-colored, brown-headed grubs or brown beetles working in the tobacco. Upholstered furniture often has holes eaten by these grubs and beetles.

[1] *Lepisma saccharina* Linné and *Thermobia domestica* (Packard), Order Thysanura, Family Lepismatidæ.

[2] *Lasioderma serricorne* Fabricius, Order Coleoptera, Family Anobiidæ.

Food.—Tobacco products and dried leaves; upholstered furniture, materials used in stuffing furniture, dried plant products, especially those used as drugs, black and red pepper, and many others.

Distribution.—Throughout the United States and southern Canada.

Life History, Appearance, and Habits.—The adult beetle is rounded in outline, of a very light-brown color, and only about $\frac{1}{16}$ inch in length. The wing covers are not striated, and the antennæ are of the same thickness from base to tip (Fig. 500, *c*, *d*, *e*). The eggs are laid in and about the substances on which the insects feed. The larvæ are white, curved-bodied, quite hairy little grubs, up to $\frac{1}{12}$ inch in length. Their heads are very light brown. They pupate in silken cocoons covered with bits of their food material. The entire life cycle may be passed in from 45 to 50 days and there are commonly three to six generations a year.

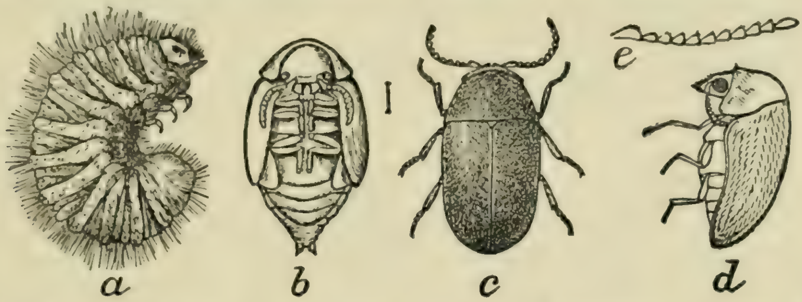


FIG. 500.—Tobacco beetle, *Lasioderma serricorne* Fabricius. *a*, larva; *b*, pupa; *c*, adult, dorsal view; *d*, adult, side view; *e*, antenna. Enlarged. Line indicates natural size. (*From U. S. D. A. Farmers' Bull.* 846.)

Control Measures.—Infested tobacco factories, warehouses, or other premises should be thoroughly cleaned, removing all refuse material on which the beetles may be feeding, in cracks or behind boards or crevices about the walls or floors. All infested material should be removed, or piled loosely in the house, and fumigated with hydrocyanic acid gas, used at the rate of 1 ounce of sodium cyanide, or the equivalent of calcium cyanide, to each 100 cubic feet of space. Fumigation should be applied by the method described on page 254. Heating to 130 to 135° F. is quite effective. The heat must be applied long enough to penetrate all parts of the infested material, and then be maintained for at least three hours. Overstuffed furniture may be freed of these beetles by thoroughly wetting it with a good grade of gasoline.

References.—*U. S. Dept. Agr. Dept. Bull.* 737, 1919, and *Farmers' Bull.* 846, 1917; *Furniture Manufacturer*, Vol. 34, December, 1927.

Drug-store Beetle[1]

This insect closely resembles the tobacco beetle in its life history and habits. Its food is even more varied than that of the tobacco beetle,

[1] *Sitodrepa panicea* (Linné) Order Coleoptera, Family Anobiidæ.

and includes practically all dry plant and animal products. The adult is about 1/10 inch long, of a reddish-brown color, and densely covered with very short light hairs. The wing covers are plainly striated, and the antennæ enlarged at the end (Fig. 501, *c*, *d*, *e*). The larva (*a*) differs from the tobacco beetle in being nearly bare.

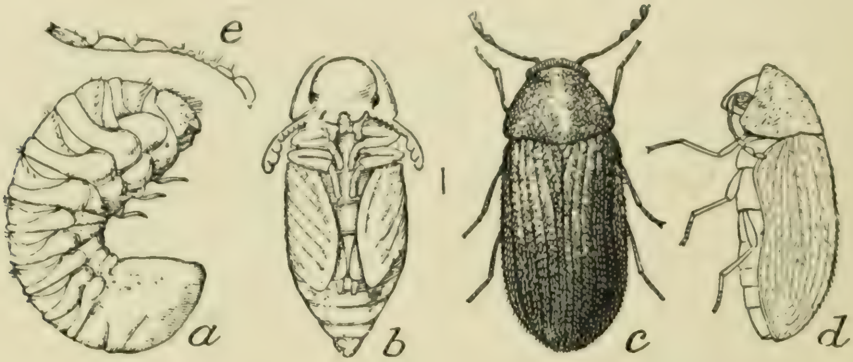


FIG. 501.—Drug-store beetle, *Sitodrepa panicea* (Linné): *a*, larva; *b*, pupa; *c*, adult dorsal view; *d*, adult, side view; *e*, antenna. Enlarged. Line indicates natural size. (*From U. S. D. A. Bur. Entomol. Bull.* 4.)

CARPET BEETLES OR BUFFALO BEETLES[1,2,3]

Importance and Type of Injury.—Holes are eaten in fabrics, especially carpets, by dark-brown, very hairy larvæ which taper toward the tail (Fig. 502). These larvæ are about 1/4 inch long. Some of the species[2] have a long tail of black hairs (Fig. 503). There is no webbing together of the fabric nor silken threads spun over the surface as is the case with clothes moths. Small, blackish, hard-shelled beetles are often seen in the infested materials. Most severe injury occurs in materials that have lain undisturbed for some time.

Food.—Woolen goods of all kinds; sometimes cotton goods; leather, bristles, feathers, hair, silk, dried insect specimens, stuffed animals, fur, grains, flour, and many other animal and plant products.

Distribution.—Two of the most destructive species of carpet beetles have been imported from Europe, these being the common carpet beetle,[1] and the black carpet beetle.[2] These and several other species[3] occur generally in this country.

Life History, Appearance, and Habits.—Of the many species of carpet beetles, or, as they are sometimes called, buffalo beetles, which occur in this country, all have a somewhat similar life history. The adults are small, somewhat oval beetles, from 1/8 to 1/6 inch in length. The adult of the common carpet beetle, which may be taken as an example of the others, is about 1/8 inch in length, oval in outline, with irregular white and red markings on its black wing covers (Fig. 502, *d*). The eggs are

[1] *Anthrenus scrophulariæ* Linné, Order Coleoptera, Family Dermestidæ.

[2] *Attagenus piceus* Olivier, Order Coleoptera, Family Dermestidæ.

[3] *Anthrenus muscorum* (Linné), *Anthrenus verbasci* (Linné) and others.

laid on the food materials, and hatch in about 10 days. The young larvæ at first increase very rapidly in size. They molt from 5 to 11 times in the course of their growth, and the cast skins quite closely resemble, and often are mistaken for, living larvæ (*a*). It requires from less than 1 year, to as much as 3 years for the larva to complete its growth, the length of time depending on climatic conditions and food. The pupal stage (*c*) is white and soft, and is passed inside the larval skin

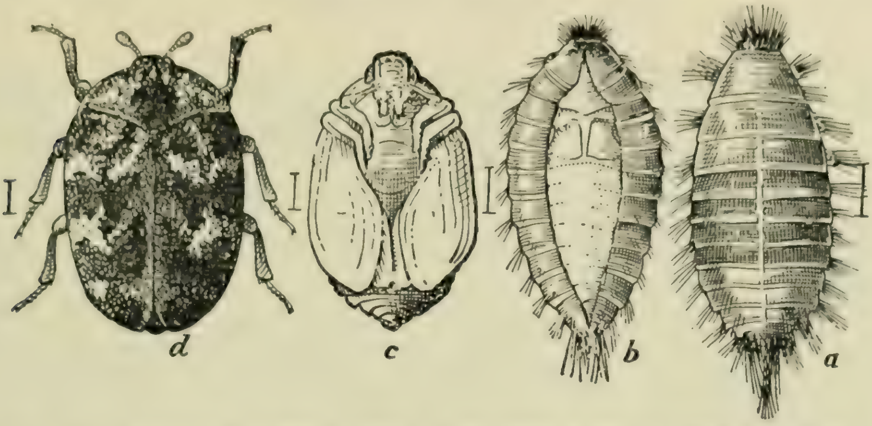


FIG. 502.—The common carpet beetle, *Anthrenus scrophulariæ* Linné; *a*, larva; *b*, pupa within larval skin; *c*, pupa removed from larval skin, ventral view; *d*, adult. All enlarged; lines indicate natural size. (*From Riley U. S. D. A.*)

(*b*) but without the protection of a cocoon. This stage lasts a little over 2 weeks. The adult beetles may be found in heated buildings at any time during the year, but are usually most abundant during the spring and summer months. They are strong, active fliers, and feed on a great variety of flowers. They frequently gain access to houses by flying into windows, or other openings in the house, or may be brought in on bouquets of flowers.

FIG. 503.—The black carpet beetle, *Attagenus piceus* Olivier; larva, five times natural size. (*From Herrick "Insects Injurious to the Household," copyright, 1914, by the Macmillan Company. Reprinted by permission.*)

Control Measures.—All species of carpet beetles may be controlled by fumigating with hydrocyanic acid gas, or with carbon bisulfide, used at the strengths recommended on pages 253 to 259. Paradichlorobenzene used at the rate of 1 pound to each 10 cubic feet of space, will kill all stages of the beetle. It is rather expensive, however, to use this material at such a strength in houses. Naphthalene used at 1 pound to 10 cubic feet of space in tight containers is also effective in killing the beetles.

Cedar chests will not kill these insects. No loss from carpet beetles will take place in goods held in storage at 50° F., or lower. Heating to 135° F. for 3 hours, will kill all stages of the insects, but care must be taken in using this method that the desired temperature is maintained in the center of the articles treated (see page 263).

Reference.—U. S. Dept. Agr. Farmers' Bull. 1346, 1923.

Clothes Moths

Importance and Type of Injury.—There are several species of clothes moths that are responsible for damage in this country, the most common being the case-making clothes moth,[1] the webbing clothes moth,[2] and the tapestry moth.[3] Fabrics injured by clothes moths have holes eaten through them by small, white caterpillars; and, in most cases, the presence of the insect is indicated by silken cases or lines of silken threads over the surface of the materials. Materials left undisturbed for some time or stored in dark places are most severely injured by these insects. Small, buff-colored moths, not over ½ inch across the wings, will be found running over the surface of infested goods when such goods are exposed to light, or flying somewhat aimlessly about in houses or closets. The clothes moths are not attracted to lights.

Food.—The clothes moths feed on wool, hair, feathers, furs, upholstered furniture (Fig. 17), occasionally on dead insects, milk powders, such as casein and nearly all animal products, such as bristles, dried hair, and leather.

Distribution.—Clothes moths are distributed generally over the world.

Life History, Appearance, and Habits.—The adult "millers" or moths (Fig. 504, *a*) are entirely harmless and probably take no food of any sort. They lay their eggs singly on the products in which the larvæ feed, each female laying from 100 to 150 eggs. Occasionally, with some species, the eggs may be laid in groups. They are small, being about one-tenth the size of a pinhead (1/50 inch long), of a white color, which makes them rather conspicuous when deposited on black material. The larvæ (Fig. 504, *b*, *c*) which hatch from these eggs, are the only stage of the insect causing damage. They are white, and vary in size from about 1/16 inch long, when first hatched, up to a little over ¼ inch when full-grown. The length of the larval period varies greatly according to the conditions and food supply. The complete development of this stage may take from 8 weeks to nearly 4 years. The larvæ of some species live in silken cases (*b*) which are dragged about with them and enlarged as they grow. Upon completing its growth, the larva adds to the silk of the case in which it has been living, forming a rather tough cocoon. Within this

[1] *Tinea pellionella* Linné, Order Lepidoptera, Family Tineidæ.
[2] *Tineola biselliella* Hummel, Order Lepidoptera, Family Tineidæ.
[3] *Trichophaga tapetzella* Linné, Order Lepidoptera, Family Tineidæ.

case (*d*) it changes to a white pupa, about 1/6 inch in length. The pupa later turns brown and in 3 or 4 weeks the adult moth emerges. In heated buildings, the adults may be found at any time of the year, but are most abundant during the summer months.

Control Measures.—Clothing which is in daily use is practically never infested by the clothes moths. It is highly important that clothing, or other fabrics placed in storage, should be free from moths. To insure this, such clothing should be thoroughly brushed and shaken and hung

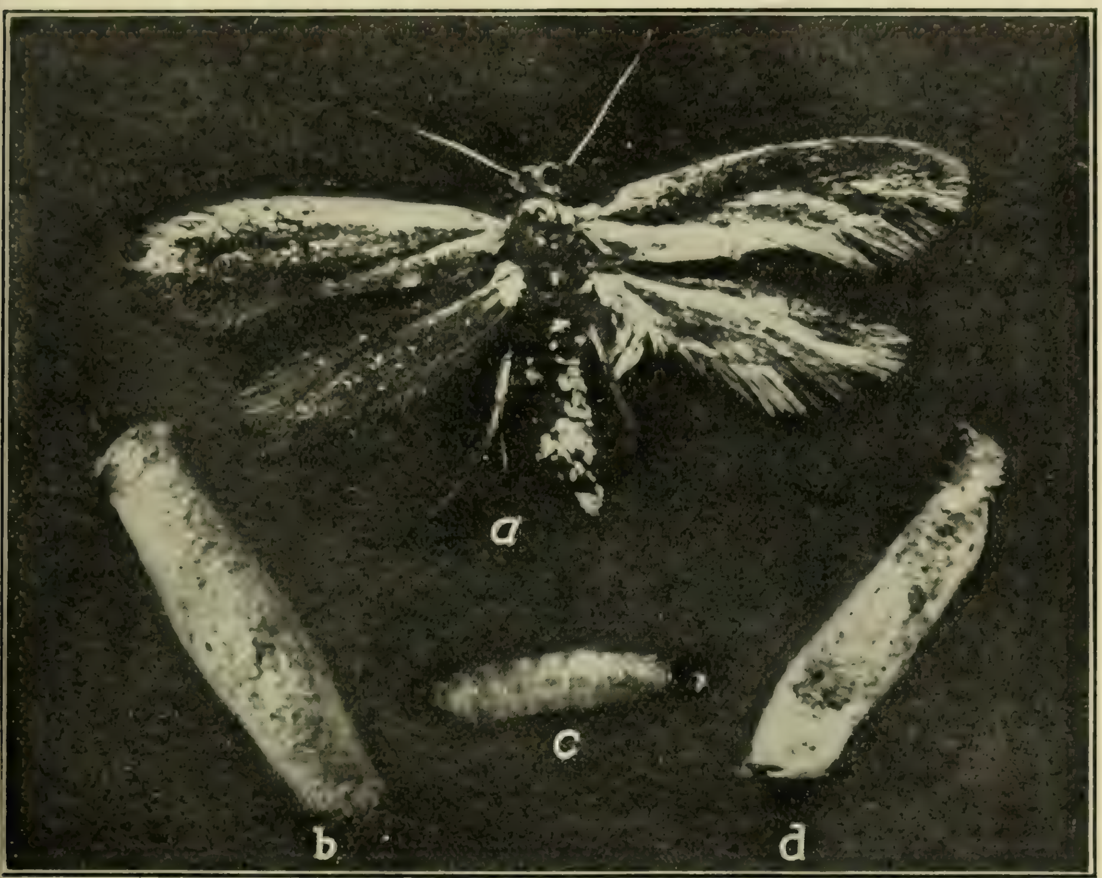


Fig. 504.—The case-making clothes moth, *Tinea pellionella* Linné, *a*, adult; *b*, larva in case; *c*, larva removed from its case; *d*, cocoon enclosing pupa. About seven times natural size. (*From Ohio Agr. Exp. Sta. Bull.* 253.)

out-of-doors in the bright sun for several hours before being packed away. If placed in trunks or boxes, clothing may be protected from infestation by scattering naphthalene flakes through the box or trunk at the rate of 1 pound to 10 cubic feet of space. Paradichlorobenzene used in the same way, will also give complete protection, and will kill any larvæ or other stages of the insect which may have been in the material when it was placed in storage.

Carbon bisulfide may be used for fumigating infested material and will kill all stages of the insects. To insure completely freeing clothing of moths with this material, a second fumigation should be given about 3

weeks after the first. Fumigation with hydrocyanic acid gas, at the rate of 1 ounce to each 100 cubic feet of space is also effective in controlling this insect (see directions for fumigating on pages 253 to 259).

Tight-fitting cedar chests will protect clothing from attacks of the clothes moths and will kill larvæ hatching from the eggs within the chest. However, partly grown larvæ placed in such chests may complete their development and cause considerable damage. Heating, as recommended for the carpet beetle, will kill all stages of the clothes moths. No damage to clothing will occur if kept in cold storage at 45° F., or lower.

References.—U. S. Dept. Agr. Farmers' Bull. 1353, 1923; *U. S. Dept. Agr. Dept. Bull.* 1051, 1922; *Furniture Manufacturer*, Vol. 35, No. 1, n. s., January, 1928.

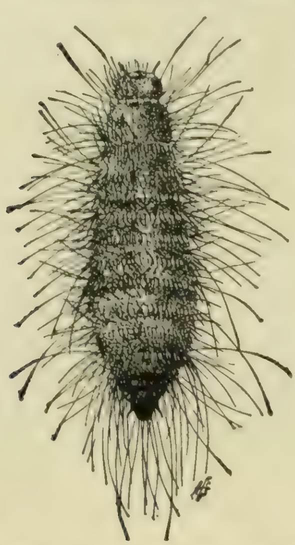
Larder Beetle[1]

Importance and Type of Injury.—Very hairy, brown larvæ (Fig. 505), tapering towards both ends of the body, feed on meats and animal products of nearly all kinds.

Food.—Feathers, horn, skins, hair, beeswax, ham, bacon, dried beef, and like products.

Distribution.—World-wide.

Life History, Appearance, and Habits.—The adult beetles are about ⅓ inch long, of a very dark brown color, and with a moderately wide yellowish band across the front part of the wing covers. There are six black dots in this band, three on each wing cover, usually arranged in a triangle (Fig. 505). The eggs are laid on the food or in sheltered places near-by. The larvæ, on hatching, increase rapidly in size. They feed chiefly near the surface of the infested materials and become full-grown (a little over ⅓ inch long) in 40 to 50 days. Pupation takes place in the larval skin. The exact number of generations, and some details regarding the length of the stages, are not known. The adult beetles will occasionally be found in numbers out-of-doors on flowers, where they feed on pollen.

a 

b 

Fig. 505.—The larder beetle, *Dermestes lardarius* Linné. *a*, larva; *b*, adult. About four times natural size. (*From Herrick, "Insects Injurious to the Household," copyright, 1914, by the Macmillan Company. Reprinted by permission.*)

Control Measures.—Smoked meats kept in farm storehouses, should be carefully sacked or wrapped in paper, muslin, or other cloth immediately after smoking, care being taken that the entire piece of meat is covered and no openings or cracks left through which the beetles may gain access to the meat. Smoked meats held in cold

[1] *Dermestes lardarius* Linné, Order Coleoptera, Family Dermestidæ.

storage will not become infested. If meat storerooms or larders become infested, they should be heated to 130 to 135° F. for 3 hours, or fumigated with carbon bisulfide or hydrocyanic-acid gas. All meat in the storeroom should be removed before treatment is applied and the infested parts of such meat should be carefully trimmed off and burned.

References.—*U. S. Dept. Agr. Div. Entomol. Bull.* 4, n. s., p. 107, 1902; *Canadian Entomol.* Vol. 38, p. 68, 1910; Herrick's "Household Insects," p. 272, 1921.

Cheese Skipper[1]

Importance and Type of Injury.—Small, naked, yellowish maggots crawling in and over cheese or meat (Fig. 506), or jumping for short distances by bending their bodies nearly double and then suddenly straightening them.

Fig. 506.—The cheese skipper, *Piophila casei* (Linné); eggs, larvæ or "skippers," pupæ and adult flies. Four times natural size. (*From E. O. Essig, University of California.*)

Food.—Cheese and meats.

Distribution.—World-wide; probably imported into this country.

Life History, Appearance, and Habits.—The adult insects are small, rather shiny, two-winged flies, a little less than $\frac{1}{6}$ inch in length (Fig. 506). They lay their eggs in clusters of about 50, although occasionally depositing a single egg. The eggs hatch in about 36 hours into small fleshy maggots which are legless and taper towards the head end. They are yellowish-white in color, and about $\frac{1}{5}$ inch in length when full-grown. These larvæ may complete their growth in 1 week. They then change to a very light-brown puparium and remain in this stage for about 1 week to 10 days. The entire life cycle may be passed in 3 weeks.

Control Measures.—Infested portions of cheese or ham should be cut away and burned. Where cheese is stored, care should be taken that the grubs are kept out of the storeroom by tightly closing all openings or by using very fine screen or cloth to protect windows open for ventilation. Frequent examinations should be made of cheese in storage to see that no infestation has started. Bandages used for covering cheeses should be kept as firm and smooth over the cheese as possible. Where serious infestations have started in storerooms, they should be fumigated with hydro-

[1] *Piophila casei* (Linné), Order Diptera, Family Piophilidæ.

cyanic acid gas or thoroughly cleaned out, and the walls and entire room washed with very strong soap suds, using the soap at the rate of 3 to 4 ounces to the gallon of water. The water should be as hot as possible while the washing is done. Screens with a mesh larger than 30 to the inch will not prevent the entrance of these flies. Cheese held in storage at temperatures below 43° F. will not be infested by the cheese skipper.

References.—*U. S. Dept. Agr. Dept. Bull.* 1453, 1927; *Calif. Agr. Exp. Sta. Bull.* 343, 1922.

Cheese, Ham, and Flour Mites[1]

There are a number of species of mites, which are creatures closely related to spiders, that infest ham, cheese, flour, and other food products. They are all of a whitish color, and so small as to be barely discernible to the naked eye (Fig. 507). They vary in size, the largest being only about $\frac{1}{32}$ inch long. When they are abundant, a musty, sweetish odor is given off by the infested products, which is quite characteristic. Occasionally a rather intense irritation of the skin is caused by the mites where one has been handling food products infested by them. This has received the descriptive name of grocer's itch (see page 848).

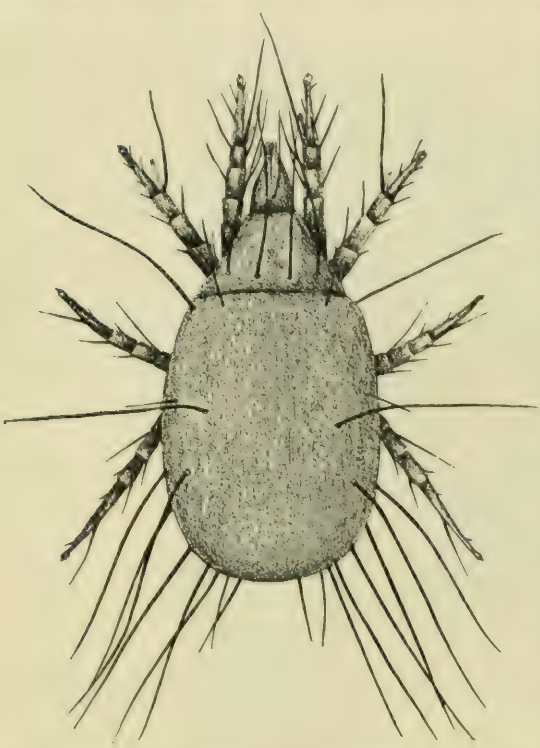


Fig. 507.—Cheese or ham mite, *Tyroglyphus* sp. Greatly magnified. (*From Minn. Agr. Exp. Sta. Bull.* 198.)

The mites reproduce by means of eggs, which are laid promiscuously over the food materials. The young mites grow rapidly, being six-legged at first, but eight-legged on becoming adults. When conditions are unfavorable, the mites pass into a semi-resting stage, known as the *hypopus*. In this stage the body wall hardens, the legs are largely withdrawn within the wall, and no feeding takes place. The mites may remain in this condition for a number of months without food, but when conditions become favorable to their growth they molt and again become active. This peculiar adaptation enables them to survive for considerable periods, and for this reason premises once infested are often difficult to clean up.

Control Measures.—All infested materials should be carefully gone over, and that which shows serious injury discarded. Infested parts of hams or cheeses should be cut off and burned. Storerooms should be thoroughly fumigated with sulfur, using the sulfur at the rate of 2 to 3 pounds per 1,000 cubic feet. In rooms where the oil is not objectionable, the walls, floor, and ceilings should be sprayed with some light oil, such as gasoline or a deodorized kerosene. As the mites thrive best where the humidity is rather high, keeping storerooms as dry as possible will tend to prevent infestation. It has been found that the mites cannot live for any length of time, except in the hypopus stage, where the humidity is less than 11 per cent. However, when mites are working on food, they give off moisture which often raises the humidity to a point

[1] *Tyroglyphus siro* Linné, *Tyroglyphus farinæ* De Geer, and *Tyroglyphus longior* Gerv., Order Acarina, Family Tyroglyphidæ.

favorable to their development. Hydrocyanic acid gas is said not to be effective for the control of these mites.

References.—*Minn. Agr. Exp. Sta. Bull.* 198, 1921; *U. S. Dept. Agr. Div. Entomol. Bull.* 4, n. s., 1902; *Insect Life*, Vol. 4, p. 170.

B. INSECTS ATTACKING STORED GRAIN, SEEDS, AND GRAIN PRODUCTS

Granary Weevil[1] and Rice Weevil[2]

Importance and Type of Injury.—These two true weevils (Fig. 508) are perhaps the most destructive grain insects in the world. They frequently cause almost complete destruction of grain in elevators, in farm-

Fig. 508.—Above, the granary weevil, *Sitophilus granariæ* (Linné), adult beetle about eleven times natural size. Below, the rice weevil, *Sitophilus oryzæ* (Linné), about twelve times natural size. (*From Ill. State Nat. Hist. Sur.*)

ers' bins, or on ships where conditions are favorable to their growth and the grain is undisturbed for some length of time. Infested grain will usually be found to be heating at the surface, and may be damp, sometimes to such an extent that sprouting occurs. Many small brown beetles, with distinct snouts projecting from their heads, will be found working over and in the grain. The kernels of grain are eaten out or contain small, legless, fat-bodied, white grubs feeding on the interior.

Food.—Wheat, corn, macaroni, oats, barley, sorghum, kaffir seed, buckwheat, and other grain and grain products.

Distribution.—The granary weevil is probably not native to North America. The rice weevil is supposedly a native of India. Both species have been distributed all over the world in shipments of grain.

Life History, Appearance, and Habits.—The adult granary weevil is a somewhat cylindrical beetle, about $\frac{1}{6}$ inch in length. It is dark brown,

[1] *Sitophilus granaria* (Linné), Order Coleoptera, Family Curculionidæ.

[2] *Sitophilus oryzæ* (Linné), Order Coleoptera, Family Curculionidæ.

or nearly black in color, with ridged wing-covers, and a prolonged snout extending downward from in front of the head for a distance of about one-fourth the length of the body. The rice weevil has much the same general appearance, although on the whole it will average somewhat smaller. There are usually two patches of somewhat lighter, yellowish color on the front and back of each wing cover. A distinguishing mark is in the shape of the small shallow pits on the prothorax of the beetles: in the rice weevil these are round (Fig. 508, *lower figure*), in the granary weevil (*upper figure*) they are oval.

The female weevil chews slight cavities in the kernels of grain or in other foods, and there deposits small white eggs, one in a cavity. The eggs hatch in a few days into soft, white, legless, fleshy grubs which feed on the interior of the grain, hollowing it out, and, on becoming full-grown, are about $\frac{1}{8}$ inch in length. They change to naked white pupæ and later emerge as adult beetles. The entire life cycle may be passed under favorable conditions in from 6 to 7 weeks. In Kansas, there are from four to five generations of the insect each season. The rice weevil has well developed wings, and frequently flies, especially during periods of high temperature. The granary weevil has the wing covers somewhat grown together, and is unable to fly. In other respects, the two insects closely resemble each other in their life histories and will very frequently be found associated and working together in the same bins.

Confused Flour Beetle[1]

Importance and Type of Injury.—This insect is one of the most common occurring in situations where grain products are stored. It is one of the most annoying pests in retail grocery stores and warehouses. Infested material will show many elongate, reddish-brown beetles, about $\frac{1}{7}$ inch long (Fig. 509), crawling over the material when it is disturbed; and brownish-white, somewhat flattened, six-legged larvæ feeding on the inside of the grain kernels and crawling over the infested seeds. They are generally known among millers as "bran bugs."

Food.—This insect feeds on a great variety of products, including all kinds of grains, flour, starchy materials, beans, peas, baking powder, ginger, dried plant roots, drugs, snuff, Cayenne pepper, and many other foods.

Distribution.—The insect was first noted in this country in 1893. It is now known to occur throughout the world.

[1] *Tribolium confusum* Duval, Order Coleoptera, Family Tenebrionidæ. The rust-red flour beetle, *Tribolium ferrugineum* (Fabricius), is very similar to the confused flour beetle. The two may be distinguished in the adult stage by the following differences: the confused flour beetle has the antennæ gradually enlarged toward the tip, the rust-red flour beetle suddenly enlarged at the tip; the margin of the head is notched at the eyes in the confused flour beetle, and not so notched in the other species. The rust-red species seems to be less common.

Life History, Appearance, and Habits.—The adult beetles are very active, moving rapidly when disturbed. The very small, clear white eggs are laid on sacks, in cracks, or directly on the food material. These hatch in 5 days into small brownish-white worms, which become full-grown in one month and are then about $\frac{1}{6}$ inch in length. They change to white, naked pupæ, remaining in this stage for 3 to 5 days. A complete generation is passed in 3 to 4 months when the temperature is high. Under Kansas conditions, four or five generations occur annually in heated store houses or mills. All stages of the insect may be found at any time of the year in such buildings.

FIG. 509.—The confused flour beetle, *Tribolium confusum* Duval. Adult, about fourteen times natural size. (*From Ill. State Nat. Hist. Sur.*)

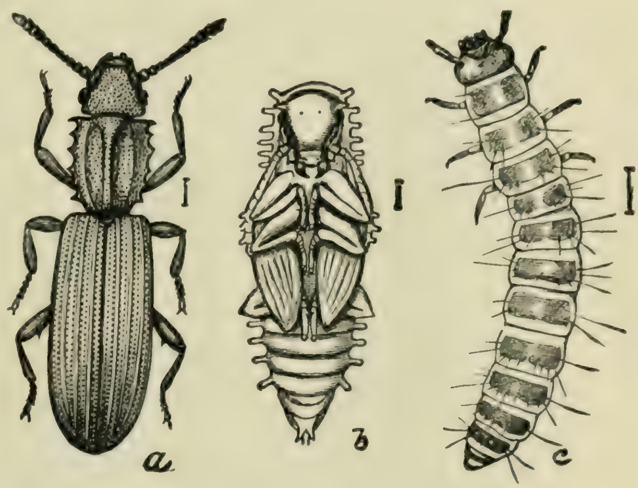


FIG. 510.—The saw-toothed grain beetle, *Oryzaephilus surinamensis* (Linné): *a*, adult; *b*, pupa; *c* larva. Lines indicate natural size. (*From U. S. D. A.*)

SAW-TOOTHED GRAIN BEETLE[1]

Importance and Type of Injury.—Infested material will show many very slender, much flattened, small, dark-red beetles hurrying over the surface of the food. Feeding consists of scarring and roughening of the surface of the food, and of eating holes through it, as is the case with the granary weevils.

Food.—As with the confused flour beetle, this insect feeds on a great variety of products including practically all grains and grain products, dried fruits, breakfast foods, nuts, seeds, yeast, sugar, candy, tobacco, snuff, and, in fact, almost all plant products used for human food.

Distribution.—Throughout the world.

Life History, Appearance, and Habits.—The adult beetles (Fig. 510, *a*) are dark-brown, flattened, slender insects, about $\frac{1}{10}$ inch long. When

[1] *Oryzaephilus surinamensis* (Linné), Order Coleoptera, Family Cucujidæ.

examined under a lens, six saw-tooth-like projections will be seen on each side of the thorax. The eggs are laid on and near the food and hatch in about 1 week. The larvæ (*c*) are brown-headed, elongated, white, six-legged grubs. They feed for nearly 3 weeks, then form a protective covering by sticking together small bits of the food material. When full-grown, the larvæ are about $\frac{1}{8}$ inch in length. They remain in the pupal stage (*b*) for from 6 to 12 days, emerging at the end of this time as adult beetles. There are from four to six generations annually throughout most of the United States. It is possible, under very favorable conditions, for the entire life cycle to be passed in from 24 to 30 days.

Reference.—Jour. Agr. Research, Vol. 33, pp. 435 to 452, 1926.

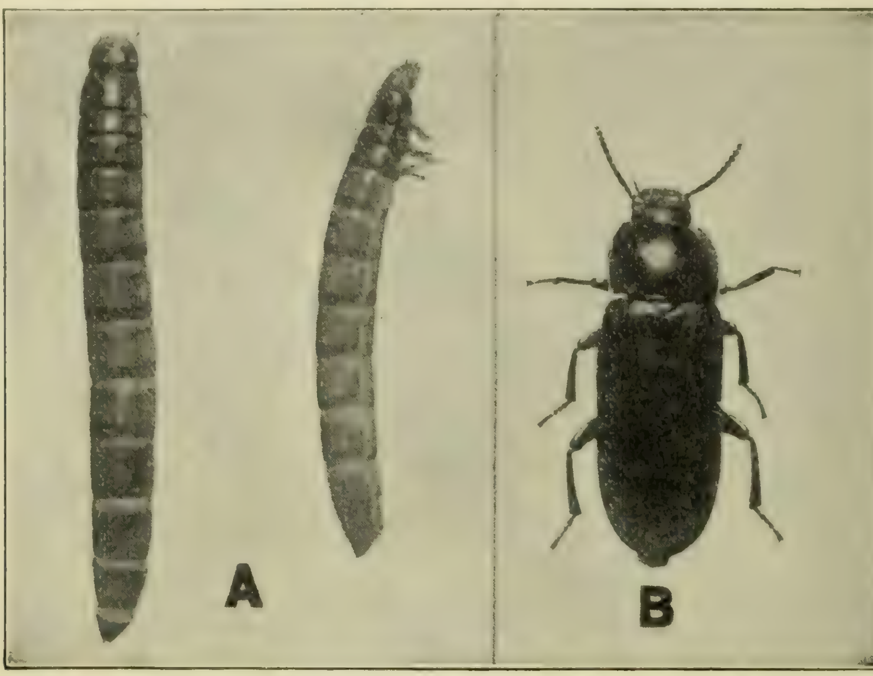


Fig. 511.—Yellow meal worm, *Tenebrio molitor* Linné; *A*, larvæ about twice natural size; *B*, female adult, two and one-half times natural size. (*From Kans. Agr. Exp. Sta. Bull.* 189.)

Meal Worms[1]

Importance and Type of Injury.—Yellowish to brown, smooth, shiny-bodied worms, closely resembling wireworms, and large black beetles up to 1 inch long, feeding in and around grain bins, particularly where the grain has not been disturbed for some time.

Food.—Cereals and cereal products, including meal, bran, and some other food products.

Distribution.—The insects are natives of Europe. They are now distributed throughout the world.

Life History, Appearance, and Habits.—The adults of the two meal worms rather closely resemble each other. They are black to nearly

[1] *Tenebrio molitor* Linné, and *Tenebrio obscurus* Fabricius, Order Coleoptera, Family Tenebrionidæ.

black beetles, robust, flattened, somewhat shining, from ½ to nearly 1 inch in length (Fig. 511, *B*). The female deposits her eggs singly or in clusters in the food materials. The eggs hatch in from 2 to 3 weeks into white larvæ which become yellow in color as they grow. When full-grown, they are 1 to 1½ inches in length, and very closely resemble wireworms in appearance (*A*). The larval period usually requires from 6 to 9 months. The pupal stage is white, and is passed without any cocoon or protective covering. The two species of meal worms can be separated only by a careful examination, and have practically the same life history and habits. They are always most abundant in damp grains, or grain products that have remained undisturbed for some time.

CADELLE[1]

Importance and Type of Injury.—This insect is sometimes very important as a pest of stored grains; but is also, to some extent, a feeder upon other insects. When abundant, however, it becomes seriously destructive in grain bins. It also causes damage in flour mills by cutting holes in flour sacks, silk bolting cloth, and other silk cloth used in the machinery.

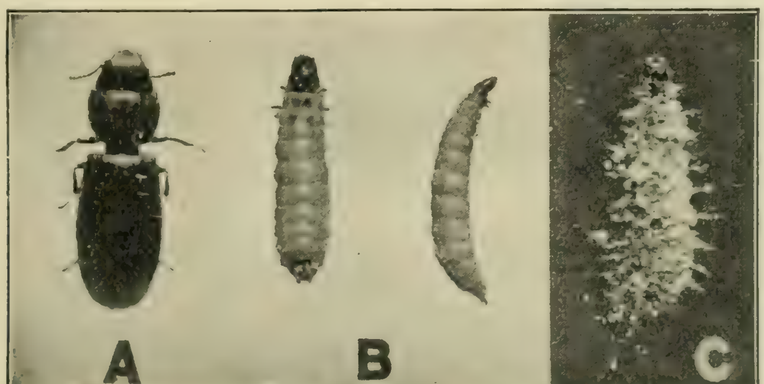


FIG. 512.—The cadelle, *Tenebroides mauritanicus* Linné. *A*, adult beetle, three times natural size; *B*, larvæ about twice natural size; *C*, larva coated with flour, about twice natural size. (*From Kans. Agr. Exp. Sta. Bull.* 189.)

Food.—The insect is a general feeder on stored grains and seeds. It usually attacks the embryo, eating out only the softer parts of the grain. While it will often kill and feed upon other insects with which it comes in contact, its general habits are not those of a predaceous insect.

Life History, Appearance, and Habits.—This insect is, next to the meal worms, the largest of those attacking stored grains. The adult beetle (Fig. 512, *A*), is black, or nearly black, ⅓ to ½ inch in length, with the head and prothorax distinctly separated from the rest of the body, to which it is attached by a rather loose, prominent joint.

[1] *Tenebroides mauritanicus* Linné, Order Coleoptera, Family Ostomidæ.

The eggs are laid on or near the food, by preference in cracks, under flaps of cartons, or in some such protected situation, commonly being deposited in groups of 10 to 60. The larvæ that hatch from these eggs (Fig. 512, *B*) are rather soft-bodied, white to grayish-white in color, with prominent black heads, black spots on the first segment of the thorax, just behind the head, and two short dark hooks at the rear end of the body. They are about ⅔ inch long when full-grown. Under favorable conditions the larvæ may complete their development in from 70 to 90 days; others require from 7 to 14 months. Full-grown larvæ and adults have the habit of boring into wood, adjoining the grain on which they have been feeding. The pupa stage is passed in such cavities or in other secluded places. Female adults commonly live for a year, and some specimens have been kept alive from 15 to 22 months.

Reference.—U. S. Dept. Agr. Dept. Bull. 1428, 1926.

FIG. 513.—Ear of corn heavily infested by the Angoumois grain moth, *Sitotroga cerealella* Olivier; showing emergence holes of the moths. Reduced one-half. (*From Ill. State Nat. Hist. Sur.*)

Angoumois Grain Moth[1]

Importance and Type of Injury.—Grain in bins or ear corn in storage has small buff moths flying about the bins or crawling rapidly over the surface of the grain when it is disturbed. One or two small round holes eaten in the kernels of infested corn (Fig. 513) or in other grain. This insect is the most destructive grain moth occurring in this country, and occasionally attacks grain in the field before it is harvested. It is extremely bad in the South, causing great damage to corn in cribs.

Food.—Wheat, corn, and other grains.

Distribution.—The insect received its name from having been first reported as injurious in the Province of Angoumois, France, about 1736. It was imported to America many years ago, although the exact date is not known. It is now distributed throughout the United States.

Life History, Appearance, and Habits.—The adult insect is a rather delicate moth, about ½ inch in length, of a buff color. The hind wings

[1] *Sitotroga cerealella* Olivier, Order Lepidoptera, Family Gelechiidæ.

are uniformly light gray, with a heavy fringe of hairs; and the membrane is prolonged at the apical angle like a thumb or finger. The female moths lay from 60 to 90 eggs, singly, or in clusters of as many as 20, on the grains where the larvæ feed. Where the insects are working out-of-doors, the eggs are attached to wheat heads in the field or to the grain in the shock. They hatch in from 7 to 10 days, and the worm-like larvæ at once burrow into the kernels or berries of the grain, feeding upon the starchy parts of the kernel. In wheat, usually only one larva is found in a kernel, although several may find sufficient food in one kernel of corn. When full-grown the larvæ are about ⅕ inch long, white in color, with yellowish heads, six true legs, and four pairs of prolegs. They then spin a thin silken cocoon within the grain and there change to the pupal stage. The adult moth emerges through a small round hole in the seed coat. The larval stage lasts from 20 to 24 days and the entire life cycle may be passed in about 5 weeks. In unheated buildings, there are probably two generations a year in the latitude of Kansas and central Illinois. In the warmer parts of the South, as many as six generations occur annually. In heated buildings, such as storehouses or mills, breeding is continuous throughout the year.

References.—*U. S. Dept. Agr. Farmers' Bull.* 1156, 1920; *Jour. Econ. Entomol.* Vol. 11, p. 87, 1918.

Mediterranean Flour Moth[1]

Importance and Type of Injury.—The Mediterranean flour moth is, without much question, the most troublesome insect occurring in flour mills in this country. Where this insect is present, masses of flour in shoots and elevators will be found webbed together and containing small pinkish-white caterpillars. The shoots may become entirely clogged and the machinery stopped by these webbed masses of flour. Small gray moths will also be noted flying about the infested buildings.

Food.—Flour is the favorite food of the insect, but it will attack also the whole grain of wheat, bran, breakfast foods, corn, and other grains.

Distribution.—The insect was first reported in North America in 1889, when it was found in Canada. It has now spread throughout the United States and Canada, and probably throughout most of the world.

Life History, Appearance, and Habits.—The adult moth (Figs. 514, *B*, *C*, *D*) is of a pale-gray color, and is a little less than ½ inch long. The head and tail are slightly raised when the insect is resting, this being quite characteristic. The wings are marked with two zigzag lines of black which are not prominent. The eggs are laid in accumulations of flour or other foods, or in cracks about buildings, or on the cloth in spouts or bolters in mills. They hatch in from 3 to 6 days, depending on the temperature. The caterpillars immediately begin spinning silken

[1] *Ephestia kuehniella* Zeller, Order Lepidoptera, Family Pyralididæ.

threads which form into little tubes in which they live and feed. It is this web spinning that causes the greatest amount of damage by the insect. The caterpillars when full-grown are about ⅗ inch long, of a general whitish to pinkish color (Fig. 514, *A*). They pupate in silken cocoons, this stage lasting from 8 to 12 days. Under conditions encountered in mills, the entire life cycle is usually passed in from 9 to 10 weeks.

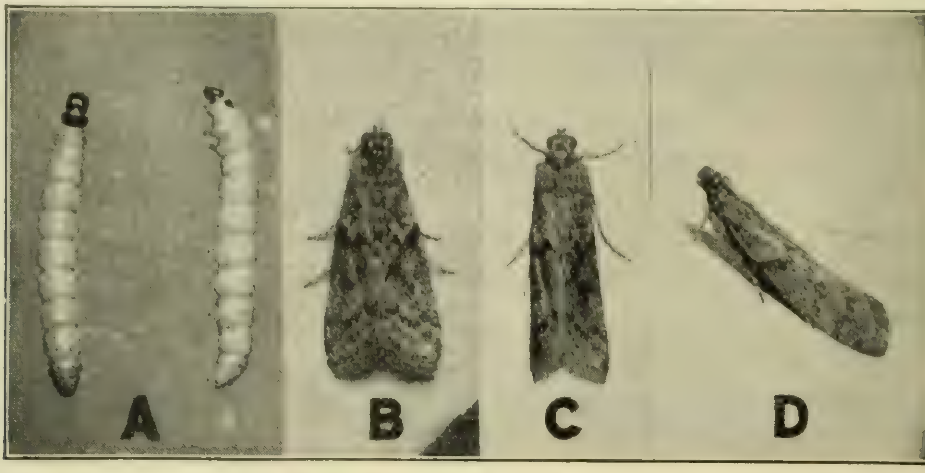


Fig. 514.—Mediterranean flour moth, *Ephestia kuehniella* Zeller. *A*, larvæ, *B* and *C*, adults, dorsal view; *D*, position of moth when at rest, from side. Twice natural size. (*From Kansas Agr. Exp. Sta. Bull.* 189.)

Indian Meal Moth[1]

Importance and Type of Injury.—The Indian meal moth feeds on a great variety of food materials. Infested material will be more or less webbed together and often fouled with dirty silken masses containing the excreta of the larvæ.

Food.—This insect attacks all kinds of grains, meal, breakfast foods, dried fruits, nuts, seeds, dried roots, herbs, dead insects, museum specimens, the wax in bee hives, and many other substances. It is frequently a pest in candy factories where nut candies are made and has been bred from milk chocolate not containing nuts.

Distribution.—The insect is of European origin, but is now generally distributed throughout the United States.

Life History, Appearance, and Habits.—The adult moth is about ½ inch in length. When at rest (Fig. 515, *A*) the wings are folded closely together along the line of the body. The front or base of the forewings is a grayish-white color, and the tip half or two-thirds is a contrasting reddish-brown; the underwings are grayish-white. The minute eggs, to the number of 350 or more, are deposited in clusters of from 12 to 15. They hatch in about 4 or 6 days, into small caterpillars, of a general white color, but often with a distinct greenish tinge. On becoming full-grown,

[1] *Plodia interpunctella* Hübner, Order Lepidoptera, Family Pyralididæ.

these caterpillars are about $\frac{1}{3}$ to $\frac{1}{2}$ inch in length. They pupate within a thin silken cocoon, from which the adult moths emerge in 10 to 12 days. The entire life cycle of the insect will require from $4\frac{1}{2}$ to 6 weeks under conditions usually encountered in heated buildings, there being from four to six generations of the insect each year.

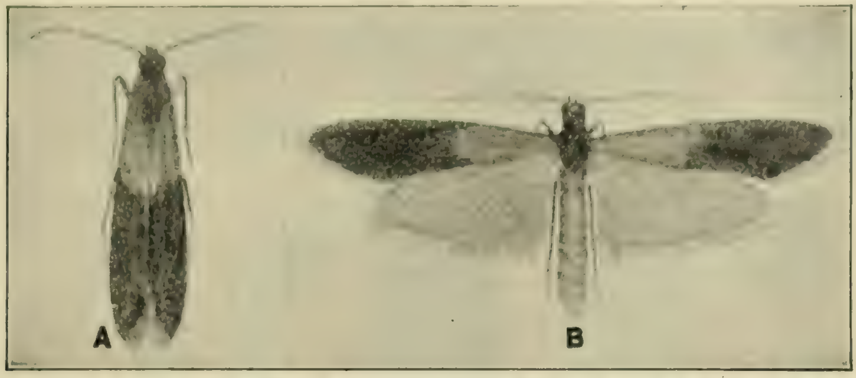


Fig. 515.—Indian meal moth, *Plodia interpunctella* Hübner. *A*, adult with wings closed: *B*, adult with wings spread. (*From Kans. Agr. Exp. Sta. Bull.* 189.)

Methods of Controlling Stored-grain Pests

While the methods used for controlling insects infesting farmers' grain bins and elevators differ somewhat from those used for the control of the same insects in mills, warehouses, retail stores, and dwellings; the most effective means of preventing damage is the same. In all cases this consists of keeping the premises as clean as possible. This means the gathering up and removal of all refuse grain, seeds, grain products, or other material in which the insects breed; thoroughly cleaning the bins, store rooms, or warehouses at periods of the year when they can be emptied; the carrying over from year to year of as little material as possible; and the careful inspection of all material when brought in for storage or processing. When bins, mills, seed houses, or warehouses are built, the insect problem should be given due consideration, and the construction should be such that the most effective control measures may be applied at the minimum expenditure of effort and expense. Provision should be made in mills for heat-treating, and bins and storehouses should be made sufficiently tight for effective fumigation. Any building where grains or grain products or seeds are held in storage for some time, is practically sure to become infested sooner or later and to require treatment.

Destruction by Heat and Cold.—The heat treatment has given the best results for treating mills, retail stores, or storerooms in dwellings, as it can usually be applied so that practically all insects are killed; and the expense of treatment is lower than that of any other method. The heat treatment should be used during the period when the outside temperature is high. In most mills, the heating system used in the

winter will be sufficient to maintain temperatures high enough to kill the insect life in the mills during the summer, when outside temperatures are from 90 to 100° F. and little wind is blowing. Repeated tests with this method have shown that, in mills of fairly tight construction under the above conditions, it is possible to maintain temperatures from 120 to 150° F. for several hours and that such temperatures are fatal to all insects exposed to them. This method is coming into more general use in flour mills, but, owing to the construction of the buildings, or the lack of heating facilities, it cannot always be applied effectively. In most mills, however, the expense of installing sufficient heating units will not be so great as that of annually fumigating with hydrocyanic acid gas or some other fumigant. Heat is not satisfactory for the treatment of nuts and dried fruits.

There are a number of heat-treating machines now on the market, through which grain may be passed as it is moved from one bin to another, and subjected during its passage through the machine to high temperatures. Such machines are frequently very valuable, particularly for use in elevators or mills, where conditions are such that frequent infestations are sure to occur from the waste grain about the building and from grain being brought in.

Where outside winter temperatures go as low as 20° below zero, opening the building to this temperature will kill most grain-infesting insects. In elevators and mill storage bins, it is often possible to keep down insect damage by frequently moving the grain from one bin to another, as the insects do not thrive and multiply rapidly in grain that is frequently disturbed.

Fumigation with Carbon Bisulfide.—In general, the most effective method of treating grain bins or elevators, where the bins contain grain infested by insects, is to fumigate, using carbon bisulfide. In some cases, mixtures of carbon bisulfide and carbon tetrachloride have been recommended. The general properties of carbon bisulfide are described on page 258, under Insect Control. In bin or elevator fumigations, the material should be applied at the rate of at least 1 pound to 100 cubic feet of space.

Fumigation with Hydrocyanic Acid Gas.—The general methods of fumigating with this gas have already been described on pages 254 and 255. The same methods should be followed in the treatment of warehouses or storerooms where grain insects are causing injury. Hydrocyanic acid gas cannot be relied upon to penetrate more than a few inches into a mass of seeds, flour, or stored grain.

Fumigation with Sulfur.—Sulfur fumigation is the most effective means of cleaning out infestations of mites in bins or warehouses. Grain or grain products must be disposed of before the sulfur fumigation is applied, as the sulfur fumes are injurious to grains. From 2 to 3

pounds of sulfur per 1,000 cubic feet of space should be used for such fumigations.

C. INSECTS ATTACKING STORED PEAS AND BEANS

Pea Weevil[1]

Importance and Type of Injury.—Most housekeepers and seedsmen are familiar with "buggy" peas. The insides of the seeds in storage are eaten out by short, chunky beetles (Fig. 516, *a*) about ⅕ inch long, of a general brownish color, flecked with white, black, and grayish patches;

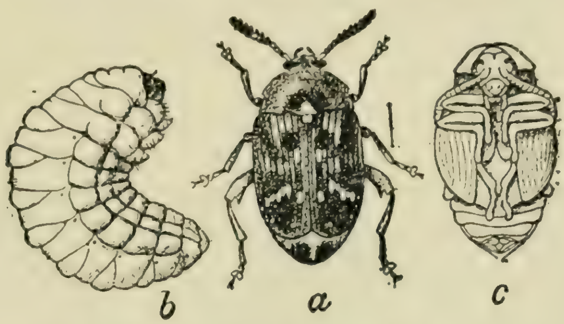


Fig. 516.—Pea weevil, *Mylabris pisorum* (Linné); *a*, adult beetle; *b*, larva or grub; *c*, pupa. The line shows the natural length of the beetle. (*From Fernald's "Applied Entomology," after U. S. D. A.*)

and by the larvæ (*b*) which are white all over except for the small brown head and mouth parts. In the spring and summer many of the old peas are found with neat circular holes, about 1⁄10 inch in diameter, leading into the cavity where the insect developed. Heavily infested peas are often reduced to mere shells. Green peas are infested with the minute larvæ, but there are only the dot-like entrance holes to show that they are not sound at this stage, and they are generally overlooked and eaten. If buggy peas are planted, a poor stand of weak, unproductive plants results and the new crop is likely to be infested.

Plants Attacked.—Peas.

Distribution.—Throughout the country.

Life History, Appearance, and Habits.—The winter is passed in the adult stage and, under northern conditions, chiefly in the peas either in the field or in storage. Some, however, and in the South many, of the beetles leave the seeds in the fall and hibernate in protected places out-of-doors. If infested seed is not treated the beetles may be planted with it. They wait until the plants are in blossom and then join others that wintered out-of-doors, about the young plants and feed on the leaves. The females glue their elongate yellowish eggs to the outside of the pods, from 1 to a dozen or more on a pod. The tiny yellowish larva that hatches from the egg is well adapted with spines and very short legs to burrow through the pod until it reaches one of the developing seeds, which

[1] *Mylabris pisorum* (Linné), Order Coleoptera, Family Mylabridæ.

it enters. Having found a place where it no longer needs to search for food, the larva loses its spines at the first molt and the legs become very short. The grub grows slowly, consuming a third or more of the contents of the seed and finally eating an exit passage to the surface of the pea, leaving only a thin circular lid (the outer seed coat) intact to protect its tunnel. It then paints the walls of its burrow with a gluey secretion from the mouth and in this snug chamber passes the pupa stage (Fig. 516, *c*), which occupies about 2 weeks in late summer.

There is only one generation a year and only one weevil matures in a pea. Eggs are never laid on dried peas, and there is no increase in numbers in storage. The adults must get to the growing plants in the spring or perish without laying eggs.

Control Measures.—The only practical controls are directed against the beetles in the seed. The best control is to tie the seed up in bags at the time of harvesting and, as soon as dry, to fumigate it with carbon bisulfide. Use 1 ounce for each bushel of seed or 3 pounds to 100 cubic feet of space in the fumigating box. This may be done in any tight barrel or box that has a close lid, or in a tight granary. The seeds should be put in first, several gunny sacks placed on top of them, the carbon bisulfide poured over the sacks, and the lid put in place. After 24 to 36 hours, remove the seeds from the fumigating box and allow them to air out. Choose a day for the work when the temperature is about 70° F. Keep cigars and all other lights and fires away from the liquid and its fumes, since the chemical is inflammable and explosive. Do not plant badly infested seeds even after the weevils have been killed. A simple control measure is to hold over seed peas in tight bags or boxes from which the adults cannot escape, until the second year after they were grown. The weevils may be killed by suspending the seeds in a bag of cold water and heating it to 140° F., then pouring the peas out on a surface where they will dry quickly. Or the seeds may be heated dry at a temperature of 135° F. for 3 or 4 hours and thus all stages of the beetle be killed without injuring germination.

Reference.—Crosby and Leonard, "Manual of Vegetable-garden Insects," pp. 54–66, 1918.

Bean Weevils

The broad-bean weevil[1] is almost identical in appearance and habits with the pea weevil, but only about two-thirds as large. It can be distinguished by the points given in the key. It prefers the European broad-bean as food, but attacks also peas and vetches. The only other important difference appears to be that several individuals occur in a single seed in contrast with the invariable one of the pea weevil. It occurs in California.

[1] *Mylabris rufimanus* (Boheman), Order Coleoptera, Family Mylabridæ.

The best-known species attacking beans is the common bean weevil,[1] which is thought to be native to the American continent. The four-spotted bean weevil[2] and the cowpea weevil[3] are closely related species that have very similar habits. They prefer cowpeas in which to develop, but attack various kinds of beans and peas, at least in storage. They can be distinguished from the bean weevil by the characters given in the key.

Importance and Type of Injury.—All kinds of beans and peas stored for seed or food, unless they are protected, are almost sure to be devoured and rendered useless by these hungry weevils. In the field the beans may be stunted and deformed so as to be worthless, but often the infestation in green beans is not detected and the infested beans are eaten or stored

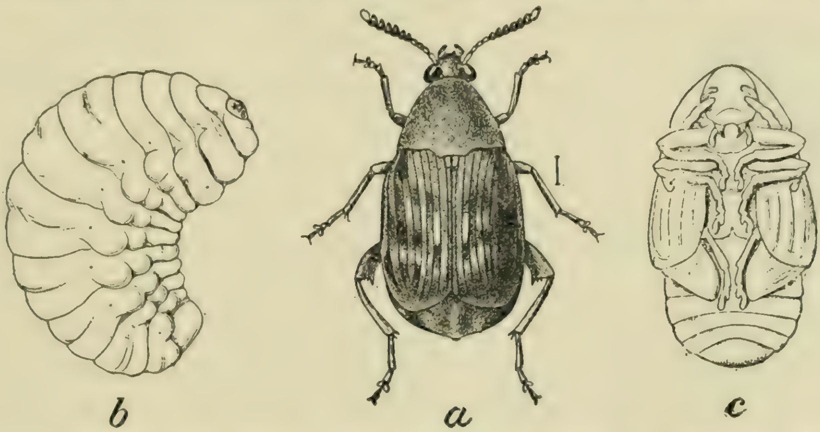


FIG. 517.—Common bean weevil, *Mylabris obtectus* (Say); *a*, adult; *b*, larva or grub; *c*, pupa. The line indicates the actual length of the beetle. (*From U. S. D. A. Farmers' Bull.* 1275.)

by the unsuspecting. These weevils are so destructive in the South as practically to prevent the commercial production of beans either for seed or for food.

Plants Attacked.—Kidney beans, lima beans, and cowpeas, in the field; and all varieties of beans, peas, and lentils and some other leguminous seeds in storage.

Distribution.—The bean weevil occurs throughout the United States and in many other countries. The broad-bean weevil is confined to the western coast, while the four-spotted bean weevil and the cowpea weevil are more abundant in the Southern States.

Life History, Appearance, and Habits.—Unlike the pea weevil and the broad-bean weevil, these species breed continuously in the dry seeds, if they are stored in a warm place, and all stages may be found in winter. In the spring the adults escape from storerooms or are carried to the field and planted with infested seeds. They appear upon the plants as the latter come into bloom and feed on the foliage slightly. The adults are only half as large as the pea weevil, of a general light olive-brown color,

[1] *Mylabris obtectus* (Say).

[2] *Mylabris quadrimaculatus* (Fabricius).

[3] *Mylabris chinensis* (Linné).

mottled with darker brown and gray (Fig. 517, *a*). They are about ⅛ inch in length, the appendages are reddish, and the body narrows evenly toward the small head. The eggs are laid in loose groups of a dozen or more, in holes chewed by the female in the green pods along the seam where the two parts of the pod meet or in any natural crack that she finds in the pod.

The minute, whitish, hairy grubs that hatch from the eggs are equipped with short slender legs and they scatter throughout the pod, seek out the developing seeds and eat their way to the inside. On account of their very small size the entrance holes heal over and leave only a slight brown dot to show the presence of the weevils within. After feeding a few days the larvæ molt and appear as white grubs with very small heads, no legs, and no long hairs. Feeding and growth continue until the larvæ are about ⅛ inch long, nearly half as thick, wrinkled, and humpbacked (Fig. 517, *b*). The pupa stage (*c*) is passed in the larval cell, which has been cemented over on the inside to exclude the larval excrement from contaminating the pupa, and which has a cylindrical extension to the outside but not penetrating the thin seed coat. Through these circular holes (Fig. 518) the adults escape 2 to 8 weeks after the larvæ entered the seeds. Adults emerging from seeds out-of-doors soon seek out growing beans and deposit their eggs upon them. If the weather remains warm, several generations may develop in the field. When beans are harvested, all stages may be taken into storage and the adults as they transform continue to lay eggs on or among the beans. Breeding goes on steadily as long as there is any food left in the beans and the temperature is warm enough. Six or seven generations may be completed in a year, and as many as 28 weevils have been known to develop in one bean.

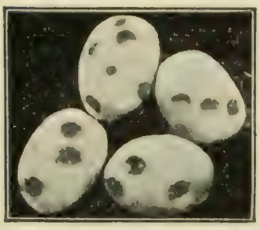


FIG. 518.—Navy beans showing emergence holes of bean weevils, about natural size. (*From Fernald's "Applied Entomology."*)

Control Measures.—When beans are harvested they should be at once sacked up tightly and, as soon as they are dry, either fumigated or heated as described for the pea weevil. Under no circumstances should weevily beans be planted, since this carries the infestation into the field and also results in a poor stand of unthrifty plants. A simple method of killing the weevils and preventing their destructive increase during the winter was discovered by Z. P. Metcalf, who recommends storing the seeds in dry air-slaked lime, 1 pound for each 2 pounds of peas, or for large quantities 1 pound to 4 pounds of peas.

References.—CROSBY and LEONARD, "Manual of Vegetable-garden Insects," pp. 57–65, 1918; *U. S. Dept. Agr. Farmers' Bull.* 1275, 1922; *Jour. Econ. Entomol.* Vol. 10, pp. 74–78, 1917; *Ky. Agr. Exp. Sta. Bull.* 213, 1917; *Jour. Agr. Research*, pp. 606–616, 1923 and pp. 347–356, 1924; *Tex. Agr. Exp. Sta. Bull.* 256, 1919.

CHAPTER XXII

INSECTS INJURIOUS TO DOMESTIC ANIMALS

For insects to attack living animals is a hazardous method of securing food. Unlike plants and stored foods, animals actively retaliate when insects attack them. Yet thousands of species of insects are specialized in structure or habit to secure all their food from the bodies of animals, and there is not a kind of wild or domesticated animal living that is not attacked by from one to many kinds of external or internal parasites.

So far as we know, no one has given us an accurate estimate of the loss that this attack upon our useful animals causes to man. We know that valuable animals, from the smallest chicks to the largest beef animals, are sometimes killed outright; that the flow of milk from dairy cattle decreases greatly during "fly time;" that beef and show cattle lose flesh and condition when flies or ticks are bad; that work horses are less efficient, often unmanageable, when annoyed by these pests; that lousy poultry, cattle, or sheep cannot be perfectly healthy; and that a number of deadly diseases are carried from animal to animal solely by the bites of insects and ticks. So it seems safe to say that this group of insects is deserving of much more careful study and active opposition than has been accorded to it.

A. INSECTS ATTACKING HORSES, MULES, AND DONKEYS

FIELD KEY FOR THE IDENTIFICATION OF INSECTS INJURING HORSES, MULES, AND DONKEYS

A. *Free-flying insects that alight on the animals to suck blood, coming and going repeatedly:*

1. Large, heavy bodied, swift-flying, black, gray, or brownish, two-winged, often green-eyed flies, ½ to 1 inch long, with wings clear or banded, usually alight on head or shoulders and suck blood on warm sunny days. A drop or two of blood exudes from the puncture after they leave. *Horseflies* or *deer flies*, page 768.

2. Flies about the size and general appearance of the house fly, suck blood, especially about the legs, causing animals to stamp their feet. Distinguished from the house fly by stiff, pointed beak or proboscis that projects forward from lower side of head, by broader, black-spotted abdomen and grayer appearance, and by arista having hairs on upper side only. Palps less than half as long as proboscis. Sits generally with head up. *Stable fly*, page 770.

3. Small, gnat-like, humpbacked flies, not more than one-fourth the size of the house fly, attack the animals, especially about the eyes, ears, and nostrils, and crawl into the hair to suck blood. Most abundant in spring. *Black flies* or *buffalo gnats*, page 772.

4. Slender-bodied, scaly-winged, long-legged, two-winged insects, up to ½ inch long, especially abundant about lowlands and swamps at dusk or at night. *Mosquitoes*, page 827.

B. Insects that stay on the animals all of the time:

1. Wingless, flattened, chestnut-colored lice, about 1/12 inch long, that feed on the dry skin and hairs, but do not pierce the skin or draw blood. Head large, short, and broad, with chewing mouth parts; legs slender, abdomen not very broad. *Chewing horse louse*, page 773.

2. Wingless, flattened, blood-sucking lice, about ⅛ inch long, with long, slender head, broad abdomen and legs much thickened toward the end. *Blood-sucking horse louse*, page 774.

3. Animals rub their bodies vigorously, hairs stand erect, areas of skin with only scattered hairs remaining; skin with a fine eruption, scurfy, or covered with small yellow scabs. Minute, very short-legged, rounded mites, hardly visible without a lens, burrow into the skin, causing intolerable itching. *Mange mite*, page 775.

4. Hair comes out in patches; skin with large scabs under which live myriads of minute, longer-legged, oval-bodied mites, scarcely visible without a lens, that pierce the skin with their mouth parts but do not tunnel beneath it. *Scab mite*, page 776.

5. Leathery-skinned, flattened, long-legged, two-winged flies, about ⅓ inch long, cluster under hairs and suck blood. *Horse "tick,"* or *forest fly*, (see Herms, "Medical and Veterinary Entomology").

C. Short, chunky, spiny maggots that live in the alimentary canal and, during the spring, are passed in the droppings:

1. Elongate, whitish or yellowish eggs or "nits," glued by half their length to base of hairs, chiefly on the front legs. Light-brown bee-like flies with faintly spotted wings hover about forequarters of animals, laying these eggs in summer. During winter months thick, spiny, yellowish or pinkish maggots up to ⅔ inch long, attach to walls of stomach or duodenum; circlets of spines double, the one on ninth segment of larva nearly complete on dorsal side. *Horse botfly*, page 776.

2. Elongate whitish eggs, glued by nearly their full length to hairs chiefly under the jaws by a bee-like fly with rust-colored thorax. During winter, short, thick, spiny, pale-yellowish maggots, attach to walls of pharynx when small, sometimes cutting off breathing, and to stomach or duodenum; circlets of spines on larval segments in a single row. *Chin fly* or *throat bot*, page 776.

3. Elongate black eggs, glued to base of the minute dark hairs of horses lips by a brightly marked, bee-like fly with its abdomen white at base, black across the middle, and bright orange-red at the end. During the winter, moderately spiny, pinkish maggots attach to stomach, duodenum, or rectum (often causing an obstruction) or cling exposed about margin of anus; circlets of spines on larval segments in double rows, but the one on ninth segment widely interrupted on dorsal side. *Lip fly* or *red-tailed botfly*, page 776.

General References.—U. S. Dept. Agr. Div. Entomol. Bull. 5, n. s., 1896; Herms, Medical and Veterinary Entomology," 2d Ed. 1926.

Horseflies[1]

Importance and Type of Injury.—Horses and mules strike with their heads, twitch the skin, shake their bodies or otherwise evince sharp pain as large, heavy-bodied black or brown flies (Figs. 520 and 521), alight on the head, neck, shoulders, or back. These insects fly alongside the animals even when they are running swiftly, and bite repeatedly. If

[1] *Tabanus* and *Chrysops* spp., Order Diptera, Family Tabanidæ.

they are not dislodged by the animal, they cut through the skin with their knife-like mouth parts and suck the blood for several minutes. When they finally fly away, a drop or two of blood usually exudes from the hole they made. In swampy wooded sections animals in harness often become unmanageable and run away.

Horseflies have been suspected of being carriers of anthrax, of an oriental disease of animals known as surra, of a human disease in Utah

Fig. 519.—Larva of the horsefly, *Tabanus atratus* Fabricius. Line indicates natural size. (*From Ill. State Nat. Hist. Sur.*)

known as tularæmia, of a kind of filariasis among humans in West Africa, and of El debab an Algerian disease of horses and camels. In some of these cases the disease has been transmitted experimentally by horseflies, and in other cases there is very strong circumstantial evidence that they are carriers.

Animals Attacked.—Horses, mules, cattle, hogs, man, dogs, deer, and other wild and domesticated animals.

Fig. 520.—Adult of the horsefly, *Tabanus atratus* Fabricius; male, natural size. (*From Ill. State Nat. Hist. Sur.*)

Distribution.—Horseflies of various species occur throughout the world, being especially abundant in moist wooded areas and up to at least several thousand feet elevation in the mountains.

Life History, Appearance, and Habits.—The life histories of only a few of the many species have been studied. Apparently the winter is generally passed as nearly full-grown larvæ in the mud about lakes, streams, or wet areas of land. These maggots (Fig. 519) are 2 inches or less in length. They are pointed at each end, whitish or banded with black or brown, and with a fleshy elevated ring on each body segment. They are very tough-skinned, and in some sections are much prized as bait for fish. They become full grown in late spring, when they pass through a pupal stage of several weeks in drier mud and then the flies begin to appear in early summer. The eggs are laid on the leaves or stems of aquatic plants or trees, on stones and other objects that overhang water, or on grasses in moist swampy places; in dark-colored, wedge-shaped masses of several hundred. Nearly a week later the very

small maggots hatch, drop into the water, sink to the bottom and bury themselves in the mud or sand. Their food is small animals such as other insects, earthworms, small crustacea and other horsefly larvæ. Some have a single generation and others apparently two each year.

There are several hundred species of horseflies in the United States, ranging in size from about 1/3 inch long to nearly 1 inch long. They are mostly black or brown, sometimes striped or spotted on the body, and many of the smaller species have the wings banded with brown. The eyes are often brilliantly colored. Horseflies can usually be told from other flies by their antennæ, which are divisible into three parts, the third being long and composed of five or eight rings and often with a short thumb-like projection at one side near its base. Only the females bite, the males feeding on nectar, honeydew and the like.

Fig. 521.—Adult of the horsefly, *Tabanus sulcifrons* Macquart, female. Enlarged one-half. (*From Ill. State Nat. Hist. Sur.*)

Control Measures.—The most effective control is to drain swamp lands and wet meadows and thus eliminate many of the breeding grounds of the flies. Pouring kerosene over stagnant water is effective in trapping the adults which come to quiet pools and dip into them. It also kills the young maggots as they hatch from the eggs and drop into the water.

Covering animals with light blankets, fly nets or ear nets, helps to ward off the attacks. Repellent oils also have been used. The following mixture has been widely recommended: pine tar 1 gallon, fish oil or crude carbolic acid 1 quart, flowers of sulphur 2 pounds. It may be smeared over the ears and head or applied as a spray.

References.—*U. S. Dept. Agr. Bur. Entomol. Tech. Bull.* 12, Pt. II, 1906; *U. S. Dept. Agr. Dept. Bull.* 1218, 1924; *Nev. Agr. Exp. Sta. Bull.* 102, 1921.

Stable Fly[1]

Importance and Type of Injury.—The most injurious insect attacking horses and mules is a small fly, very similar in appearance to the common house fly, which bites the animals especially on the legs. It sometimes comes into houses, especially in stormy weather, and bites people about the ankles. Animals stamp their feet continually to dislodge these tormenting pests. The stable fly takes one or two drops of blood at a

[1] *Stomoxys calcitrans* Linné, Order Diptera, Family Muscidæ.

meal, several such meals in a day, so that each animal probably supplies hundreds, if not thousands, of fly meals a day when stable flies are abundant. As a result of the pain from the bites, the constant worry, and the loss of blood, animals lose weight, milk yield of dairy cattle is reduced, work animals become unmanageable, and sometimes animals are killed, either as the direct result of the flies or from disease induced by the flies.

While the stable fly has been suspected of transmitting anthrax, surra, swamp fever, or infectious anemia of horses, and especially the human disease known as poliomyelitis, or infantile paralysis, it has not been proved to be the usual carrier of any animal disease.

Animals Attacked.—Horses, mules, cattle, hogs, dogs, cats, sheep, goats, guinea pigs, rabbits, rats and man.

Distribution.—The stable fly occurs in all parts of the United States and throughout most of the world. In the United States it appears to be most abundant "in the Central States from Texas to Canada, where grain is grown extensively" (Bishopp).

Life History, Appearance and Habits.—In the northern states, the stable fly is believed to winter as larvæ and pupæ in wet straw piles or strawy manure. Farther south, development continues throughout the year, and all stages may be found in winter. During the warm months of the year, breeding is continuous. The length of the several life stages has been given as follows: egg, commonly 2 or 3 days; larva, commonly 2 to 4 weeks; pupa, 1 to 3 weeks; and adult probably 3 weeks. Since the adult is usually 4 to 6 days old before she lays eggs, the total average life cycle may be given as about 20 to 50 days, the longer period in cool weather.

FIG. 522.—The stable fly, *Stomoxys calcitrans* Linné. Adult as seen from above. About five times natural size. (*From U. S. D. A. Farmers' Bull.* 1097.)

The stable fly (Fig. 522) is about ¼ inch long, of a general grayish color, like the house fly. It can be distinguished from the house fly by its habit of biting, and by its mouth parts, which stick forward from under the head as a stiff, somewhat pointed, slender beak, about twice as long as the head. Both males and females suck blood as their chief food. They are active only during the day, either in the stable or in the field.

The yellowish-white maggots of the stable fly develop in masses of straw, grain, and other materials that have become water-soaked or contaminated with manure, and less extensively in the excrement of

animals unless it contains much hay or straw. Most serious outbreaks follow periods of excessive rainfall. The full-grown maggot is about $\frac{3}{4}$ inch long, tapering almost to a point at the head, and the posterior end is cut off squarely. It can be told from the house-fly larva by looking at the spiracles on the last segment of the body. In the stable fly these are small, somewhat triangular, and the two separated by twice their own width; in the house fly they are almost touching, larger, and more rounded. The insect passes a pupal stage of a week or two, in a brown puparium among the straw, and then emerges as the adult.

Control Measures.—The destruction and avoidance of conditions in which the maggots thrive offer most promise, and, while this method cannot be expected to eliminate the fly, it should be possible to reduce its numbers. Straw from threshing should be scattered over the ground and plowed under, or burned, if it is not needed for bedding or feed. If it is to be preserved for use it should be baled and stored in a dry place or else stacked carefully so that it does not become water soaked and rotten. Masses of water-soaked feed should not be allowed to accumulate around stalls or feed troughs. The prompt disposal of manure and all other accumulations of fermenting organic matter, as explained for the house fly (p. 859), will also keep this species in check.

Animals may be covered with blankets or old trousers pulled over the legs; sprayed with a mixture of fish oil 1 gallon, oil of pine tar 2 ounces, oil of pennyroyal 2 ounces, and kerosene 1 pint; or allowed to run into darkened stables with nets, brush, or sacking so arranged over the doorway as to brush off the flies as the animals enter. About dairy barns and other stables, a window trap may be used to catch myriads of the stable fly as well as house flies. This trap is made just wide enough to fit into the window. The sides, top and bottom are of wood. The outer and inner faces are of wire screen, folded full width so as to leave V-shaped, inward projecting ridges on each face. At the apex of each ridge, holes are punched every 2 inches, large enough for flies to crawl through. A crack $\frac{1}{4}$ inch wide is left at the bottom of the trap on each side and the space that flies enter there is roofed with screen also having holes at its apex. Bait may be placed in this space to attract the house flies, but is of no value for stable flies. Flies that enter through these small holes accumulate in the cages at the top and may then be destroyed. While repellent sprays and traps help in lessening the annoyance to animals, cleaning up the breeding places is of far greater importance.

Reference.—*U. S. Dept. Agr. Farmers' Bull.* 1097, 1920.

Buffalo Gnats or Black Flies[1]

These very small gnats (Fig. 551) hover about ears, eyes, and nostrils, alighting frequently and puncturing the skin with a very irritating bite.

[1] *Simulium* spp., Order Diptera, Family Simuliidæ.

The young develop in the water, especially of rocky, swift-flowing streams. They are very difficult to destroy without destroying the fish in the stream and about the only means of control is to provide smudges, in the smoke of which animals can get relief from attack, or to spray animals with repellent oils. These flies are more fully discussed under Insects That Attack Man (p. 832).

Chewing Horse Louse[1]

Importance and Type of Injury.—At least two very different species of lice attack the horse, and it is important to recognize which is present in any case of infestation, since the control measures will be somewhat different. This species does not pierce the skin or suck blood but runs freely about over the animal, nibbles at the dry skin and hairs and causes great irritation. In the spring of the year, horses that have not wintered well rub against fences, stalls, and other objects. The coat, especially on the head, withers, and about the base of the tail becomes unkempt, hairs stand erect, and the skin is dry and full of scurf.

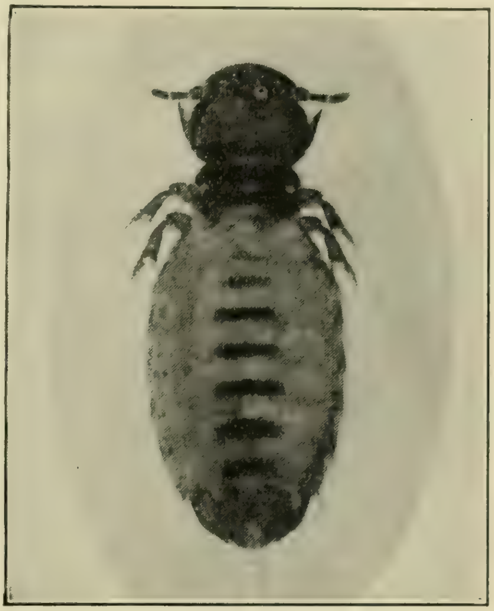


Fig. 523.—The chewing horse louse, *Trichodectes parumpilosus* Piaget; female, about twenty-five times natural size. (*From U. S. D. A. Farmers' Bull.* 1493.)

Animals Attacked.—Horses, mules, and donkeys.

Life History, Appearance, and Habits.—These lice generally become noticeable in late winter or early spring, when all stages can usually be found on the animal. The full-grown ones (Fig. 523), are about $\frac{1}{10}$ inch long, of a chestnut-brown color except on the abdomen, which is yellowish with dark crossbands. The head is much broader and shorter than that of the following species, and rounded in front, forming a full semicircle in front of the antennæ. The legs are slenderer than those of the blood-sucking horse louse. The eggs are glued to the hairs close to the skin, especially around the angle of the jaw and on the flanks. The eggs hatch in 5 to 10 days, into very small pale-colored lice of the same general shape as the full-grown ones, and they become full-grown in 3 or 4 weeks. Breeding is continuous throughout the year, but the numbers become fewer in summer.

Control Measures.—Horses are not usually troubled with lice unless they have been neglected in feeding, stabling, and grooming. Sodium

[1] *Trichodectes parumpilosus* Piaget, Order Mallophaga, Family Trichodectidæ.

fluoride dusted into the coat of the horse using about 2 ounces per animal has given complete control. It should be dusted on the coat but not rubbed in and not applied too freely about body openings. The young lice are killed by this powder as they hatch from the eggs. The animals may be washed or dipped in a 2 or 3 per cent solution of creolin in water or in one of the well-known coal-tar dips, or rubbed with raw linseed oil. If linseed oil is used, do not work the animal or expose to hot sun for a day after treatment. Whatever the treatment given, it must be repeated 2 weeks later, in order to destroy lice hatching from eggs, since the eggs are not killed by the dips.

Reference.—U. S. Dept. Agr. Farmers' Bull. 1493, 1926.

FIG. 524.—The blood-sucking horse louse, *Hæmatopinus macrocephalus* Burmeister; female, about twenty-five times natural size. (*From U. S. D. A. Farmers' Bull.* 1493.)

Blood-sucking Horse Louse[1]

Importance and Type of Injury.—This seems to be the most important louse infesting the horse, being commoner and also more irritating, because it feeds by piercing the skin and sucking the blood. The bites are painful and, when the lice become abundant, the loss of blood is a severe drain on the vitality of the host. The horse shows the same symptoms of scurfy skin, unkempt coat, and scratching or rubbing its body as in the case of the chewing louse. Often parts of the body will be rubbed raw. Only an examination of the lice themselves will determine which species is present.

Animals Attacked.—Horses, mules and donkeys.

Life History, Appearance, and Habits.—All sizes of lice and eggs will usually be found during the winter, when these insects are troublesome. The full-grown lice (Fig. 524) are of a dirty grayish or yellowish-brown color, about ⅛ inch long, by half as broad at the middle of the abdomen. The thorax is only half as wide, and the head less than a third as wide, as the abdomen, distinctly narrowed toward the front. The legs are short and very clumsy, fitted for grasping about hairs. The lice are commonest about head and neck and at the base of the tail. The egg

[1] *Hæmatopinus* (*asini*) *macrocephalus* Burmeister, Order Anoplura, Family Hæmatopinidæ.

stage is normally from 11 to 20 days, but some may hatch as long as a month after they were laid. The young lice are similar to the large ones except paler in color, and gradually grow to the size and color of the adults in 2 to 4 weeks. There are several generations a year.

Control Measures.—Sodium fluoride is not effective for this species. Raw linseed oil, 2 or 3 per cent creolin in water, or one of the commercial coal-tar dips or standard arsenical dip should be applied. Dips should not be applied in cold weather. If linseed oil is used, keep the animal out of the sun and avoid overheating for a day or two. Since the eggs hatch over so long a period, two to four treatments at intervals of 10 to 20 days, and one of these treatments at least 5 weeks after the first, are recommended.

Reference.—U. S. Dept. Agr. Farmers' Bull. 1493, 1926.

Mange Mite[1] or Sarcoptic Mange

Importance and Type of Injury.—Animals rub and scratch their bodies vigorously. Areas on the head, neck, back, or at the base of the tail, become pimply and scurfy, with the hairs bristling and only scattered hairs remaining. Later the infestation may spread over the entire body, and large, dry, cracked scabs form on the thickened skin. To distinguish it from lousiness, some scrapings from the affected skin should be examined under a microscope for the mites which cause the trouble. The mange of the horse may spread to man, causing "cavalry-man's itch," but it does not persist on man, dying out in a few weeks. See also pp. 800 and 848, and Fig. 9.

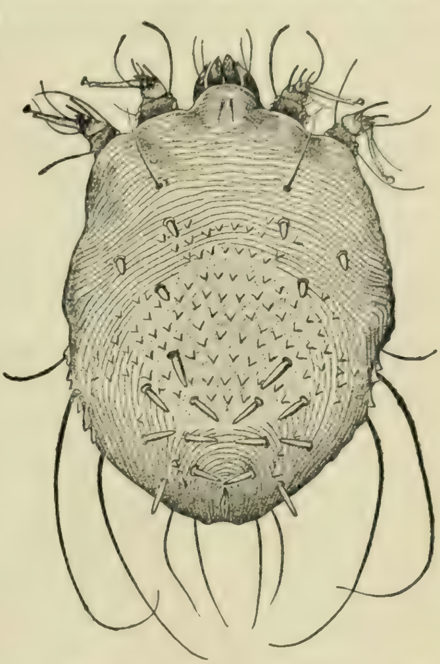


Fig. 525.—The mange or itch mite, *Sarcoptes scabiei* Latrielle; female about one-hundred times natural size. (*From U. S. D. A. Farmers' Bull.* 1493.)

Animals Attacked.—Horses, hogs, mules, men, dogs, cats, rabbits, squirrels, sheep, and cattle are attacked by different varieties of the same species.

Life History, Appearance, and Habits.—Mange is caused by a very small mite (Fig. 525), scarcely as big around as the cross-section of an ordinary pin, and with very short legs that barely extend beyond the margins of the body. It is not a true insect, but an eight-legged form related to the ticks and spiders. The mites themselves will seldom be seen except by the specialist. They burrow beneath the skin, making very slender winding tunnels from 1/10 inch to nearly 1 inch long. Within

[1] *Sarcoptes scabiei equi* Gerlach, Order Acarina, Family Sarcoptidæ.

such a tunnel, the female lays about 24 eggs, and dies at the end of the tunnel. Within 3 to 10 days the eggs hatch to minute nymphs, which are at first six-legged. At the first molting they acquire an additional pair of legs, and after two more molts they are full-sized and ready to mate. After mating the males die, the females again shed their skin, and begin new tunnels 10 days to a month after hatching from the eggs. The trouble is most evident during the winter months, but some of the mites live on the animals the year round, unless treated. A generation may be completed in 2 weeks.

Control Measures.—Mange is contagious, and the most important control is the isolation of infected animals to prevent spread. Treatment for horses consists in clipping, prolonged bathing or massaging in soap and water to soften the scabs and open up the tunnels, and applying one of the many dressings recommended for this pest. Hadwen recommends a hot (not boiled) mixture of raw linseed oil 1 gallon, oil of tar 8 ounces, and sulfur 2 pounds. Leave on the skin for 10 days; then repeat. Another preparation especially recommended not to cause loss of hair is equal parts of carbonate of soda, water, soap, sulphur, and creolin. Dissolve the soda in the water and add the others in order. Stir well and dilute with 5 more volumes of water. Rub into the affected spots for ½ hour, then wash with clean water. Repeat four times, 3 days apart. Repeated dippings in lime-sulfur solution, for 2 or 3 minutes, at 105° F., are also effective. Repeated applications of any treatment are necessary. Stalls, curry combs, harness, and other objects about the horse should be treated with a good, coal-tar-creosote disinfectant, since the mites may live on these objects for several weeks off the animal.

Reference.—U. S. Dept. Agr. Farmers' Bull. 1493, 1926.

Scab Mite[1]

The scab mite is less serious on horses than on cattle and sheep. It is sometimes spoken of as the "wet mange," in contrast with the dryer scabs that result from the attacks of the mange mite. It usually starts among the longer hair of the neck, withers, or base of tail. Treatment is the same as for mange mite. See also p. 805.

Horse Bots

There are three kinds of botflies that molest horses in this country. They are known as the common horse botfly,[2] the chin fly or throat bot,[3] and the nose or lip botfly.[4]

[1] *Psoroptes communis bovis* Hering, Order Acarina, Family Sarcoptidæ.

[2] *Gastrophilus* (*equi*) *intestinalis* De Geer, Order Diptera, Family Œstridæ.

[3] *Gastrophilus* (*veterinus*) *nasalis* Linné.

[4] *Gastrophilus hæmorrhoidalis* Linné.

Importance and Type of Injury.—All three kinds of botflies are dreaded by horses, which fight them viciously, although we know from the structure of the flies that they can neither bite nor sting the animals. Their sole object in flying about horses is to glue their eggs (Fig. 526) fast to the hairs. This act may result in a slight pull on the hair, but it is believed that the alarm caused by the flies is mostly due to fear or nervous excitation caused by buzzing and striking. The most injurious stage of the flies is the maggot or larval stage, which lives in the digestive tract of the horse, causing mechanical injuries to the lining of the stomach and intestine by the sharp spines and mouth hooks, interfering with glandular activity, causing inflammation, absorbing food, which progressively

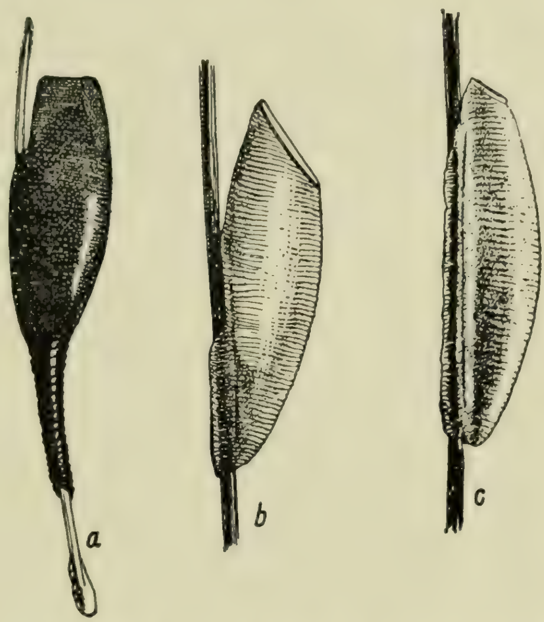


Fig. 526.—Eggs of horse bots; *a*, the lip botfly; *b*, the common horse botfly; and *c*, the throat botfly. About thirty-five times natural size. (*From U. S. D. A. Farmers' Bull.* 1503.)

starves the host, and frequently causing complete obstruction to the passage of food substances from stomach to intestine (Fig. 527). A horse badly infested with bots presents a run-down condition, due to digestive disturbances, and has a rough coat. The presence of bots may also be detected by finding the full-grown larvæ in the manure in the spring months, although this occurs too late to apply effective control measures.

Animals Attacked.—Horses, mules, donkeys, and rarely dogs.

Distribution.—The common horse bot and the throat bot occur throughout the United States. The throat bot is said to be especially abundant in the Rocky Mountain region. The nose or lip botfly is recorded from northern Illinois, westward to Idaho and from northern

Kansas and Colorado to Manitoba, Saskatchewan, and Alberta. It has been spreading in all directions.

Life History, Appearance, and Habits.—The bots winter as larvæ (Fig. 527), in the alimentary canal of the host, usually becoming full-grown by late winter or spring. They may be found in the digestive tract every month of the year; but after the first of October only small larvæ will be found, the mature larvæ having all been passed by that date. The full-grown horse bots are thick, tough-skinned maggots, blunt at the posterior end, tapering in front to the two strong mouth hooks, and with a circlet of

Fig. 527.—Horse bots, larvæ attached to lining of horse's stomach; at center, lesions where bots have been removed. About two-thirds natural size. (*From U. S. D. A. Dept. Bull.* 597.)

prominent spines around each body segment. They are about ¾ inch long, yellowish white or pinkish in color. The three kinds may be told by the characters given in the key. When growth is complete they release their hold on the walls of the stomach and pass to the ground, usually with the excrement. This fact has been taken advantage of by quacks who recommend various treatments to be given in the late winter and cite the normal appearance of bots in the excrement as a result. The bot larvæ burrow into the soil a short distance and inside their hardened skins form the pupæ, from which adults appear 3 to 10 weeks later. The adults are abroad commonly, in the case of the lip bot, from early June until late summer in the northern states, being rare in the fall; while

the common horse botfly and the throat botfly begin to appear about the first of July and are abundant until frosts. The adults look somewhat like bumblebees, being very hairy, two-winged, of a general brownish color and about ⅔ inch long. They take no food and live only from 3 days to 3 weeks. The common horse bot may easily be told by the faint smoky spots on the wings. The throat bot has a rust-red thorax, clear wings, and a prominent band of black hairs at midlength of the abdomen. The lip fly is somewhat smaller than the others and has a prominent red tail.

The common horse bot,[1] hovers about the animal without causing much excitement, bends her abdomen forward under the body, and, darting in, quickly glues an egg to a hair, usually on the front leg but also to a lesser extent on shoulders, belly, and hind legs. Egg after egg (Fig. 526, *b*) is attached in this way, so that the legs of horses on pasture or in corrals often assume a yellowish-gray cast from the large number of "nits" cemented to the hairs. A very curious fact about the eggs of this fly is that they cannot hatch without moisture and friction being applied to them. But when the lips or tongue of the horse pass over them in scratching or nibbling at the legs, they hatch very quickly (if mature enough) and the larva clings to the lips or tongue and is supposedly swallowed. Hadwen, however, believes that they burrow into the flesh of the tongue when taken into the mouth and they may reach the stomach by some more circuitous path. Having reached the stomach, 9 to 12 months are spent there, during which growth is completed, there being but one generation a year.

The throat bot[2] hovers in front of the horse, and at intervals, darts upward and glues its eggs (Fig. 526, *c*), to the bases of hairs under the head or jaw of the horse or down on the throat. This causes the animals to nod their heads, drawing the nose in toward the breast, and when loose in pastures, to stand with their heads across the shoulders of another horse. These eggs are also whitish but can be distinguished from those of the common bot by the characters given in the key. They do not require rubbing or moisture to hatch, and it is believed that the maggots crawl down the hair to which they were attached and burrow beneath the skin. Nothing seems to be known, however, of how they get from the egg to the stomach. They tend to attach to the pharynx, paralyzing the muscles that control swallowing, or in the duodenum, and are less common in the stomach. The rest of the life cycle is similar to that of the common horse bot.

The lip or nose botfly[3] is generally considered the worst species of the three. It lays its eggs, not about the nostrils, but attached very close

[1] *Gastrophilus (equi) intestinalis* De Geer, Order Diptera, Family Œstridæ.

[2] *Gastrophilus (veterinus) nasalis* Linné.

[3] *Gastrophilus hæmorrhoidalis* Linné.

to the skin on the small hairs of the lips. Striking the horse on this sensitive spot causes it to jerk and toss its head, and repeated attacks often cause the animals to become frantic or to rub their lips over fences, or to stand with the lips appressed to another animal's back. The eggs (Fig. 526, *a*) are very different from the other species, being blackish and with a slender screw-like "tail" nearly as long as the egg. Some observers contend that this screw-like piece is sunk into the flesh at the base of the hairs. Nothing is known as to how the larvæ get from the eggs to the stomach, but it is believed that they are swallowed with food or water. From this point on, the life cycle is similar to that of the other species, except that these larvæ, instead of passing with the excreta, have the habit of attaching to the walls of the rectum or to the skin about the anus for a time before dropping to the soil, causing rubbing and switching of the tail. The adults begin to appear in early June, and some are present until frost, although any individual lives only a few days.

Control Measures.—Botflies are active only in the open and during the daytime, so that animals kept stabled during the day and pastured only at night, if at all, do not become infested. A piece of canvas stretched across the underside of the head and front of the neck, from the throat-latch to the bit-rings, effectively checks the egg laying of throat botflies. The lip fly may be similarly prevented from laying eggs by a belting lip protector, constructed as described by Bishopp and Dove in *U. S. Dept. Agr. Farmers' Bulletin*, 1503. The eggs of the common horse bot may be destroyed by sponging the legs of the horse frequently with a solution of carbolic acid, containing 2 per cent phenol in water, or with a 2 per cent solution of the standard coal-tar-creosote dips. Such applications should be made every 5 or 6 days. Bishopp and Dove have found that an application of equal parts pine tar and lard prevents egg laying on the treated parts for about 4 days.

If the horse is found to be infested in fall or early winter, its digestive tract should be fumigated in the following manner. Give a light feed in the morning. The following morning give a gelatin capsule containing 3 drams carbon bisulfide, an hour later another, equal, dose, and an hour later a third and last dose. Feeding and watering may be resumed 3 hours after the last treatment. The carbon bisulfide forms a gas that kills the larvæ and they are passed in the feces. Young or small animals should be given a reduced amount of the medicine. If colic or other symptoms show up after the first dose, treatment should be discontinued and tried again at a later date. These treatments should be given by competent veterinarians and should not be attempted by unskilled workmen.

References.—*U. S. Dept. Agr. Dept. Bull.* 597, 1918; *U. S. Dept. Agr. Farmers' Bull.* 1503, 1926; *Bull. Entomol. Research* Vol. 9, Pt. 2, pp. 91–106, September 1918.

B. INSECTS ATTACKING CATTLE

FIELD KEY FOR THE IDENTIFICATION OF INSECTS INJURING CATTLE

A. *Free-flying insects that alight on the animals to suck blood, coming and going repeatedly:*

1. Heavy-bodied, swift, brownish to black flies, ½ to 1 inch long, with two clear or banded wings, alight on animals and suck their blood, usually leaving a drop or two of blood exuding from the puncture. Especially active about marshes, swampy woods, or meadows and on warm sunny days. *Horseflies*, pages 768 and 783.

2. Flies of the size and general appearance of the house fly, suck blood especially from the legs, causing the animals to stamp their feet. Distinguished from the house fly by its stiff, slender beak, sticking straight forward from under side of head, by its broader black-spotted abdomen, grayer appearance, and by the bristle on antenna, having hairs on its upper side only. Palps less than half as long as proboscis. Usually rests with its head upward. *Stable fly*, pages 770 and 783.

3. Flies similar to the stable fly, but only half as large, stand on their heads among the hairs especially of the back and sides of cattle and suck blood. Palps nearly as long as proboscis. They sometimes cluster in a mass about the base of the horns to rest. *Horn fly*, page 782.

4. Very small, stout, black flies, less than ⅙ inch long, with a humped thorax, thick, 11-segmented antennæ as long as the head, two broad, delicately veined wings, and stout legs, pierce the skin and suck the blood, especially about the eyes, ears, and nostrils, causing extreme pain. *Black flies, turkey gnats or buffalo gnats*, page 783.

5. Very slender-bodied, scaly-winged, blood-sucking flies swarming over the animals, especially at dusk and at night near swampy, wooded sections. *Mosquitoes*, pages 783 and 827.

B. *Insects that stay on the animals all of the time:*

1. Slate-gray, wingless, broad, flat, blood-sucking lice, up to ⅛ inch long and half as broad; head pointed in front. The white eggs are glued to the hairs, especially about the fore part of the body. *Short-nosed ox louse*, page 786.

2. Similar to the short-nosed ox louse but only about half as large when mature, often attaching in dense groups about head and neck. Eggs yellowish. *A blood-sucking louse, Solenopotes capillatus*, page 787.

3. Bluish, shiny, wingless lice, a little smaller, darker, much more slender and with a longer head, than the preceding. Move about but little, usually stand on their heads among the hairs. Eggs nearly black, glued to the hairs. *Long-nosed ox louse*, page 786.

4. Much smaller lice, about 1/13 inch long, reddish in color, with distinct dark cross-bands on the abdomen; head broad, bluntly rounded in front. Chew hairs, epidermal scales, etc., do not suck blood. Run about actively among the hairs. Eggs whitish, glued to hairs. *Little red louse*, page 784.

5. Hair comes out in patches; skin forms large scabs, under which may be found myriads of minute, eight-legged, oval-bodied, pale mites, just visible to the naked eye, which pierce the skin with their mouth parts but do not tunnel beneath it. *Scab mite*, page 788.

6. Hard lumps up to the size of a pea form on skin of muzzle, head, and shoulders, and burst open, disclosing a yellowish pus in which are many microscopic worm-like mites, with eight short legs toward one end of their short, slender bodies. *Follicle mite*, page 788.

7. Eight-legged, leathery, glossy, ovate, seed-like, brown to bluish-gray ticks, attached to the skin by their mouth parts and seldom moving about; up to ½ inch long. Drop off host to lay eggs in a cluster on the ground. Minute, first instar

nymphs or "seed ticks" have only six legs. *Texas-fever tick* (carries the disease known as Texas fever), *dog tick*, and others, page 788.

C. *Spiny worms or maggots that live in the flesh or in wounds:*

1. During the winter, tumorous swellings or "warbles" appear along the back, in which fat, wrinkled, white or blackish maggots, from ⅓ to 1 inch long, live; and from which they can be squeezed out. The larvæ have minute spines on all but the last larval segment. These are the young of hairy, swift flies (about the size and appearance of a honeybee, ½ inch long, with hairy legs, uniformly white tegulæ and orange hairs at end of abdomen only) that glue small, slender, yellowish eggs in rows to hairs of legs, belly, etc., in early spring. *Heel fly* or *striped ox-warble fly*, page 791.

2. Like the above, but the last two segments of the larva without spines. Adults a little larger (⅗ inch long, with legs smoother, tegulæ with a brown border, and yellowish hairs on front half of thorax as well as on base and tip of abdomen), appear later in spring and annoy cattle greatly, causing them to stampede or run madly, though they neither bite nor sting. *Northern ox-warble fly*, or "*bomb fly*," page 791.

3. Slender, whitish maggots up to ¾ inch long, blunt behind, tapering in front, and with an elevated ring at each segment, bearing short spines, burrow in wounds of animals. The eggs are laid in abrasions and fly or tick punctures, by a metallic, bluish-green fly, larger than the house fly, with three black stripes on thorax and a reddish-yellow face. *Screw worm fly*, page 795.

4. Slender whitish maggots, blunt behind, tapering in front, and ¾ inch or less in length, work in the flesh about sores, especially following dehorning. *Green bottle fly* and *black blowfly*, page 810.

FIG. 528.—Adult of the horn fly, *Hæmatobia irritans* (Linné); about six times natural size. (*From photo by Bishopp, U. S. D. A.*)

HORN FLY[1]

Importance and Type of Injury.—The horn fly is a close relative of the stable fly, and its harmful effects on cattle are very similar. It pierces the skin to suck blood, causing pain and annoyance and interfering with the feeding and resting of the animals, so that they lose weight, lose in yield of milk, develop indigestion, and suffer other disorders. These will be recognized as the small flies (Fig. 528), about half as big as the house fly or stable fly, that hover over the backs of cattle all summer long, crawling down among the hairs on the withers, back, or belly, and, with wings partly spread suck blood until a swish of the head or tail scares them up, temporarily. These flies have been suspected of transmitting anthrax.

Animals Attacked.—Cattle chiefly; also goats. Annoying to people working about cattle.

Distribution.—This insect was first found in this country near Philadelphia in 1887 and is believed to have been brought to this country with shipments of cattle a year or two before. Within 10 years it had spread over all of the United States east of the Rocky Mountains, and to

[1] *Hæmatobia irritans* (Linné), Order Diptera, Family Muscidæ.

California and Hawaii. It is now generally distributed throughout America.

Life History, Appearance, and Habits.—Horn flies probably winter as larvæ or pupæ in dung or soil. In spring they begin to appear on cattle and their numbers rapidly increase. Apparently they develop only in fresh droppings of cattle, the flies darting from an animal to the fresh dung and depositing a few eggs on the surface of the mass. The eggs are brown in color and not easy to see. The maggots hatch from these eggs in a day or so, feed in the dung and become full-grown (about ⅜ inch long), in 3 to 5 days. They then descend to the soil, form pupæ inside of brown seed-like puparia, and emerge as flies about a week later. The entire life-cycle may be completed in 10 days to 2 weeks. The adults look like half-sized stable flies, but do not have the spotted abdomen and the palps at the sides of the beak are about two-thirds as long as the beak. When not feeding they often rest about the head, especially on the base of the horn if the animal has horns, sometimes so many of them that they make a black ring around the horn. It should be clearly understood that no injury is done to the horn. The flies remain abundant until frosts kill them, when the immature stages in the dung go into hibernation.

Control Measures.—No satisfactory control for horn flies has yet been discovered. Darkened stables, with curtains or brush arranged over the entrance to brush the flies off as the cattle go in, give a measure of relief. If the cattle are being fed grain, hogs and chickens running with them help to control the flies by scattering the dung and destroying the maggots. Some countries have introduced dung-feeding beetles and predaceous wild birds which it was hoped would check the flies, but the practical method of combating this pest awaits discovery. Repellent sprays give temporary relief from these flies and are useful at milking time.

References.—*U. S. Dept. Agr. Bur. Entomol. Circ.* 115, 1910; *Jour. Econ. Entomol.*, Vol. 21, pp. 504–506, 1928.

Other Blood-sucking Flies

The large blood-sucking horseflies or greenheads (Figs. 520 and 521), often punish cattle severely, especially if the pastures border woods or wet areas of land. Mosquitoes may dry up dairy cattle and cause loss of flesh in other animals, especially in wet seasons, when they come out of the water in swarms and bite the animals day and night. Draining wet land, screening stables, and providing smudges will give relief from horse flies and mosquitoes. Black flies (Fig. 551), attack about the eyes, nostrils, or ears and under the belly, and may be sucked into the mouth or nostrils by snorting animals, which sometimes die as though suffocated by the innumerable gnats. Smudges appear to be the only practical help for this scourge. Further discussion of black flies is given on page 832. The stable fly (Fig. 522), while generally less serious on cattle than the horn fly, in times of great epidemics may exceed the latter as a cattle pest. It bites chiefly about the legs. Control measures are the same as given under Horses.

Other Flies about Cattle

A number of flies, such as the house fly, that do not pierce the skin, visit the animals to suck up blood exuding from wounds made by horn flies, stable flies, horseflies and others. They annoy the animals and may easily have a serious connection with the transmission of blood parasites from one animal to another. Other flesh flies besides the screw-worm fly sometimes deposit eggs or maggots in wounds where the maggots develop.

Cattle Lice

As in the case of the horse, two very different kinds of lice are common on cattle, some of them sucking the blood, and others, which cannot pierce the skin, living off the dry skin scales, hairs, and scabs. They are especially injurious to calves and to poorly fed, unhoused, old animals, during the winter months. The lack of oiliness of the skin of such animals makes conditions ideal for lice. Holsteins are said to be the worst infested and Jerseys the least so.

Chewing Cattle Louse or Little Red Louse[1]

Importance and Type of Injury.—When cattle rub and scratch against stanchions, fences, and other objects, and show areas of the skin which are full of scurf and partly denuded of hairs, or raw and bruised from rubbing, they are almost certainly infested either with lice or with scab mites. If lice are the cause of the irritation, parting the hairs and folds of the skin on head, neck, and shoulders will reveal the lice, while if the trouble is due to scab, no insects will be visible to the naked eye. The lice which suck blood (Fig. 530), are all of a bluish slate color, while the chewing louse (Fig. 529) is yellowish white with a reddish head and eight dark crossbands on the abdomen, giving a somewhat ladder-like appearance to this part of the body. The chewing lice crawl about freely over the skin between the hairs, irritating the skin both with their sharp claws and with their sharp chewing mandibles. When very abundant, they form colonies about the base of the tail or on the withers which may become covered over with a light scurf, in patches as big as the hand. Under this scurf the lice are feeding on the raw skin. Such gross attacks weaken the animals, check growth, and predispose the animals to other diseases.

Animals Attacked.—It is the general rule that each kind of animal has its own kinds of lice that do not feed on any other animal. Cattle lice have also been recorded from deer, but do not attack other domestic animals.

Life History, Appearance, and Habits.—Lice are most abundant during the winter, when the coat becomes thick and long and the skin is relatively dry of oil. At this season all sizes of lice and the eggs are to be found

[1] *Trichodectes scalaris* Nitzsch, Order Mallophaga, Family Trichodectidæ.

on an infested animal. The eggs, are delicate, white, barrel-shaped objects glued by one end to a hair while the other end has a slight rim within which fits a lid that is pushed off when the egg hatches. The young louse is paler in color but of the same form and structure as the old ones. It appears from the egg within a week after laying, under favorable conditions, and within 2 weeks the young louse may have become full-grown and be laying eggs for another generation. Consequently they usually increase to great numbers during the winter and early spring, if not controlled. When the coat is shed in spring and during the heat of summer, the lice seem to disappear, but enough remain to

FIG. 529.—Chewing cattle louse or little red louse, *Trichodectes scalaris* Nitzsch; female, about twenty times natural size. (*From U. S. D. A. Farmers' Bull.* 909.)

carry the species over until favorable conditions permit them to increase again.

Control Measures.—Lice cannot live off the animal for more than 7 or 8 days, but the eggs that become scattered about on shed hairs may hatch at any time up to 3 weeks and the nymphs crawl back upon the animal. Thoroughly dusting the animal's coat with sodium fluoride will greatly check if not eradicate the chewing lice. Treatment with raw linseed oil, as described under blood-sucking lice is probably the best control for a limited number of animals, and dipping, with one of the arsenical or nicotine dips, or, if good soft water is available, a coal-tar creosote preparation, in specially constructed vats is necessary for large herds.

References.—U. S. Dept. Agr. Farmers' Bull. 909, 1918; *Conn.* (*Storrs*) *Agr. Exp. Sta. Bull.* 97, 1918.

Blood-sucking Cattle Lice

Importance and Type of Injury.—The symptoms of blood-sucking lice are similar to those shown when the little red louse is present, but the irritation is greater because of their habits of piercing the skin or "biting" to get the blood. The loss of blood keeps young animals runty and prevents normal production of milk or meat in older ones. The animals scratch and rub persistently and patches of the skin become bare of hairs and are sore.

Life History, Appearance, and Habits.—If an animal infested with blood-sucking lice is examined during the winter, dark-blue patches on

Fig. 530.—Short-nosed cattle louse, *Hæmatopinus eurysternus* (Nitzsch); female, about twenty times natural size. (*From U. S. D. A. Farmers' Bull.* 909.)

the skin, often as big as a half-dollar, which at first look like dirt, may be found in folds of the skin, on head, neck, withers, or along the inner surfaces of the legs. Examining more closely will show that these spots are composed of clusters of little lice (Fig. 530), standing on their heads, clinging by their claw-like legs to the hairs, and with noses appressed to the skin, from which they draw blood. They move about very little except when laying their eggs. The largest of them are only ⅛ inch long, and successively smaller ones are generally present, down to the size of the egg. All stages are passed on the skin of the host, the eggs usually hatching in 10 days to 2 weeks. The nymphs feed continuously and the females begin to lay eggs when they are about 2 weeks old. The eggs are

glued fast to the base of the hairs by one end, and are somewhat keg-shaped.

The long-nosed cattle louse,[1] which is especially prevalent on young cattle, is a slender species about 1/10 inch long, the body one-third as wide as long, and the head nearly twice as long as broad, and pointed in front. Its eggs are nearly black. The short-nosed cattle louse[2] (Fig. 530) is the largest louse found on cattle, being 1/8 inch long and much broader than the long-nosed louse, and the head is only a half longer than broad and bluntly pointed in front. It is said, to be more common on mature cattle. The eggs are white. The third species,[3] is similar to the short-nosed cattle louse, with the head still shorter and rounded in front. It is only about half as large as the short-nosed species,[4] and its eggs, which are yellowish, are said not to hatch if removed from the host.

Control Measures.—Cattle should be well fed, kept in clean, light, well-ventilated stables, and not overcrowded. As soon as they are brought off pasture in the fall, the neck and withers should be examined for the presence of lice. These will be especially easy to see on white or light-coated animals. If even a few lice are found, all animals in the herd should be treated with raw linseed oil. Many owners make it a practice to give the treatment even if no lice are seen at this time. The oil may be applied with a hand brush that has some bristles long and some short. A pint of oil is enough to groom 4 or 5 cows, and 10 or 12 animals can be treated in an hour. At least one more application should be given, 12 to 15 days later; and three or four additional ones at similar intervals throughout the winter will assure a herd free from injury by lice. The oil should not be rubbed in too vigorously, but just enough applied so that it reaches the skin. The animals should be kept out of strong sunlight for at least 12 hours after treatment, and not overheated in any way or exposed to extreme cold. Boiled or refined linseed oil should not be used. Failure to observe these precautions may result in burning the skin. Where the number of animals is too large to permit hand applications, they may be sprayed or dipped. This should not be done in cold weather, but two or three dippings in the fall, 2 weeks apart, will practically insure clean animals the following winter. Complete directions for dipping are given in *U. S. Dept. Agr. Farmers' Bull.* 909, which should be studied before dipping is undertaken. Before treated animals are returned to their quarters, the stalls and pens should be thoroughly cleaned and disinfected by spraying with a coal-tar preparation or with kerosene emulsion.

Reference.—*U. S. Dept. Agr. Farmers' Bull.* 909, 1918.

[1] *Linognathus* (*Hæmatopinus*) *vituli* (Linné), Order Anoplura, Family Hæmatopinidæ.

[2] *Hæmatopinus eurysternus* (Nitzsch), Order Anoplura, Family Hæmatopinidæ.

[3] *Solenopotes capillatus* Enderlein.

[4] Bishopp, F. C., *Jour. Agr. Res.* Vol. 21, pp. 797–801, 1921.

Scab Mite or Psoroptic Scab

If animals that are rubbing and scratching, twitching the skin, and shaking their heads, do not show lice upon examination, cattle scab should be suspected. An examination of skin scrapings under a microscope will usually reveal the minute eight-legged mites (Fig. 541), that cause this trouble by puncturing the skin with their sharp mouth stylets. They are similar to the mange mite but can be distinguished by their longer legs and minor differences in the appendages. They do not burrow into the skin, but rest and feed upon the raw skin, completely covered over by scabs. Large scabs form on the skin over the mites and the hair comes out in great patches. This mite and its control are further discussed under Sheep, page 805.

Reference.—U. S. Dept. Agr. Farmers' Bull. 1017, 1918.

Follicle Mite[1]

A minute, worm-like mite sometimes attacks cattle, burrowing deep into the natural pores of the skin and causing lumps as large as peas to form about the head and over the shoulders. It injures the hides. The mites cannot easily be killed, and it is best to kill or market badly infected animals. Very valuable animals may be cured by persistent dipping, as for mange.

Texas-fever Tick[2]

Importance and Type of Injury.—The most destructive parasite of domestic animals throughout the Southern States is the Texas-fever tick (Fig. 531). For more than a century this pest has held back the cattle and dairy interests of the southern states, and indirectly the entire agricultural development of these states. The cattle tick is a blood-sucking parasite, and is injurious to cattle in the several ways described above for lice and flies. In addition to this it is the only means of spread of the disease known as cattle fever, tick fever, splenetic fever, or Texas fever, from sick animals to healthy ones. The principal symptoms of tick fever are a high fever, reddish discoloration of the urine, enlarged spleen, congested liver, loss of flesh and condition, dry muzzle, arched back, and drooping ears. Death results in from 10 per cent of the cases occurring during the summer months, in southern cattle, to 90 per cent of those during the autumn and early winter, especially among northern or imported stock. The cause of the disease is a minute form of animal,[3] belonging to the phylum Protozoa, that lives inside the red corpuscles of the blood and destroys them, thus causing the disease. It should be

[1] *Demodex folliculorum bovis* Stiles, Order Acarina, Family Demodecidæ.

[2] *Margaropus annulatus* Say, Order Acarina, Family Ixodidæ.

[3] *Piroplasma bigeminum.*

clearly understood that while the *direct* cause of the disease is a protozoon, the only method of spread of the disease is by the bite of the tick. If there are no ticks in a given section, there can be no Texas fever. Ticks do not pass from one animal to another, but spend their entire feeding period on a single animal. The germs of Texas fever pass through the eggs of diseased ticks to their young, however, which later get on new animals and so infect them. The presence of this disease has meant incalculable loss to the southland from the failure of diseased cattle to make beef production or dairying profitable, and especially from the "one crop system" which has prevailed largely because of the difficulty

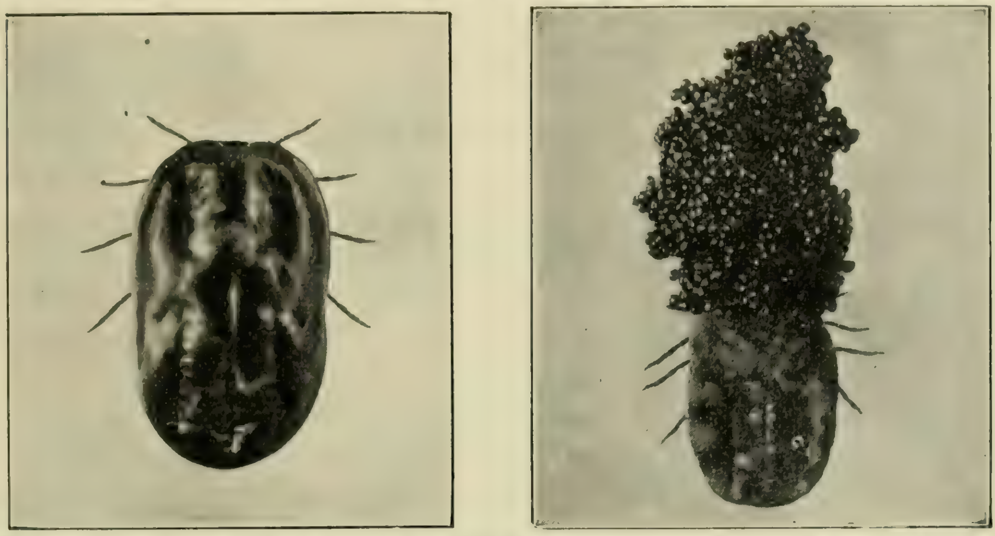


FIG. 531.—Cattle tick or Texas-fever tick, *Margaropus annulatus* Say. At left, full grown, engorged, female tick, ready to drop from animal and deposit eggs; at right, female laying eggs on the ground: each female may lay as many as 5,000 eggs. Both figures three times natural size. (*From U. S. D. A. Farmers' Bull.* 498.)

and discouragements of cattle-raising in tick-infested territory. According to the Department of Agriculture,[1] the average price of cattle in the tick territory is only about half that for similar grades in tick-free states. The hides are damaged from 50 cents to $1.25 each by the punctures of the ticks, and milk yield is reduced from 18 to 42 per cent, depending on the severity of the infestation. All in all, it is generally estimated that the tick costs southern agriculture from $40,000,000 to $100,000,000 a year.

Animals Attacked.—The Texas-fever tick is found on cattle, horses, mules, sheep, and deer, but is chiefly a pest of cattle. It does not cause fever in the other animals.

Distribution.—The Texas fever tick occurs only in the southern half of North America, in the states south of West Virginia, Kentucky, Missouri, Kansas, Arizona, New Mexico, and Nevada. The disease that it transmits is prevalent also in Central and South America, Africa, Europe, and the Philippines, where it is carried by other kinds of ticks.

[1] *U. S. Dept. Agr. Weekly News Letter,* Sept., 15, 1915.

Life History, Appearance, and Habits.—The cattle tick winters in two distinct ways in the south. Some individuals winter as eggs or minute, six-legged, "seed-ticks," about half the diameter of a pinhead ($\frac{1}{32}$ inch). They may be found on the ground or on grass, weeds, and other objects in fields where infested cattle have pastured. Other individuals winter as nymphs or adults on the skin of the cattle. When the ticks reach maturity they mate on the animal, and then the female, having fed to repletion on blood, loosens her mouth parts from the skin and drops to the ground. At this time she is nearly $\frac{1}{2}$ inch long, the body olive-green to bluish-gray, bean-shaped, with hard, glossy, and somewhat wrinkled skin (Fig. 531, *left*). Each female lays ordinarily from 1,500 to 4,000 eggs in a large brownish mass on the soil, within 2 to 6 weeks after leaving the animal. The eggs usually hatch in from 13 days to 6 weeks, but eggs may remain viable for 7 or 8 months. The young that hatch from the eggs are known as "seed ticks" (Fig. 532). They crawl about actively on the ground and climb up on vegetation, often in large bunches, and remain there waiting for an animal to come along. If an animal brushes by them they cling fast and at once insert their mouth parts and feed in that one spot for a week or two, then shed their skin and appear as nymphs with an extra pair of legs. Another period of feeding for about a week enables them to molt and transform to adult males and females. After mating, the female, still feeding, increases rapidly in size for a few days to a few weeks before she drops to the ground to lay eggs for another generation. If the seed tick is not brushed off the vegetation, it must starve to death, but may live 200 to 300 days before it perishes. There are thus four stages in the life of a tick: the egg, the seed tick, the nymph, and the adult. The life cycle is in two periods, a *parasitic* and a *non-parasitic* period. The parasitic period begins when the tiny seed tick is picked up by an animal, and ends when the fully-engorged female drops from the host. Part of the adult female's lifetime, all of the egg stage, and most of the seed tick's life are spent on or near the ground. A life cycle requires about 60 days, at the least, and there are three generations throughout most of the South.

FIG. 532.—Nymphs or seed-ticks of the Texas-fever tick, just after hatching. Eight times natural size. (*From U. S. D. A. Farmers' Bull.* 498.)

Control Measures.—A quarantine maintained by state and federal governments prevents the movement of southern, tick-infested cattle out of the quarantined area. The cattle tick cannot survive the winter in the northern states. Without the tick there can be no fever, so that cattle in the north, which are very susceptible, are protected from the

disease by the quarantine. In the South two measures of control have gone hand in hand: (1) dipping or spraying animals with arsenical dips or oil emulsions. It has been found that a farm can be completely freed of ticks by dipping all cattle, horses, and mules on the farm every 2 weeks all spring and summer, and allowing them to range over the pastures and pick up the seed ticks, between dippings; (2) rotating pasture lands, that is, keeping all animals off of certain fields until the seed ticks will all certainly have starved, and then putting on such land only cattle freed of ticks by dipping. Both of these measures have been worked out with the greatest of care and are fully described in *U. S. Dept. Agr. Farmers' Bull.* 1057. By a combination of quarantines, dipping, and pasture rotations in operation for the past 20 years, over half a million square miles of southern land have been freed of the curse of Texas fever. It is expected that this work will continue until the entire country is free of the disease.

References.—U. S. Dept. Agr. Farmers' Bulls. 498, 1912; 569, 1914; 603, 1914; *U. S. Dept. Agr. Bur. Entomol. Bull.* 72, 1907; *U. S. Dept. Agr. Misc. Pub.* 2, 1927; *Tenn. Agr. Exp. Sta. Bull.* 113, 1915.

Other Ticks

Several other species of ticks attach to cattle and suck their blood, but none of them carry Texas fever or other cattle diseases so far as known. The most serious species is the spinose ear tick[1] which is prevalent in the semiarid sections of southwestern United States. These ticks have the curious habit of entering the outer ears of cattle, horses, dogs, sheep, and other animals, where they live and feed for from 1 to 7 months. The ears may be literally packed full of these vermin, which range up to ⅓ inch or more in length. The nymphs leave the host, crawl into cracks about buildings, fences, or trees, and there shed their skins, become adults, mate, and lay their eggs. The newly hatched "seed ticks" subsequently attach to the skin of the animals which they infest. The ticks may be killed by injecting ½ ounce of a warm mixture of pine tar 2 parts, and cottonseed oil 1 part, by means of a syringe, into each ear. The dog tick,[2] which is often found on dogs, commonly attaches to cattle pastured in woodlands. The Rocky Mountain spotted-fever tick (page 842) and the lone star tick[3] also attack cattle, in regions where these ticks occur.

Reference.—U. S. Dept. Agr. Farmers' Bull. 980, 1918; and 1150, 1920.

Ox Warbles or Cattle Grubs

Two different botflies attack cattle in America: one is known as the striped ox-warble fly, for which the better name heel fly or common cattle grub[4] has been suggested; the other has been called the European or northern ox-warble fly or northern cattle grub[5] and recently the fanciful

[1] *Otobius (Ornithodorus) megnini* (Duges), Order Acarina, Family Argasidæ.
[2] *Dermacentor electus* Koch, Order Acarina, Family Ixodidæ.
[3] *Amblyomma americanum* (Linné), Order Acarina, Family Ixodidæ.
[4] *Hypoderma lineata* DeVilliers, Order Diptera, Family Œstridæ.
[5] *Hypoderma bovis* DeGeer.

name "bomb fly" has been proposed for it. There are very important differences in the habits of the two species, but their life histories and control are sufficiently similar to make their consideration together advantageous.

Importance and Type of Injury.—Tumors under the skin of the back as big as the end of one's thumb contain each a large fat maggot (Fig. 533), which may be squeezed out, but which emerges when "ripe" and falls to the ground. Hairy flies about as big as honeybees chase the animals in pastures, while laying their eggs on them. The cattle usually run wildly (Fig. 6), with tails in the air, and often injure themselves in their attempts to get away. The small maggots from these eggs tunnel into the skin and migrate through the body for about 6 months before they find lodgement in the back, causing inflammation and suffering; milk production is reduced; growth and fattening checked; the quality of the meat is lowered, where the maggots tunnel through the flesh of the back; and the value of the hides for leather is greatly depreciated. The loss from this insect has been estimated to run from $50,000,000 to $120,000,000 a year in the United States alone. Bishopp estimates that 75 per cent of the cattle in the United States are infested with from 1 to about 100 warbles each. In certain experiments a gain in milk flow of 25 per cent resulted when the grubs were removed from the back, and 5 per cent gain in weight was made by animals from which grubs were extracted as compared with similar animals in which they were allowed to develop to maturity.

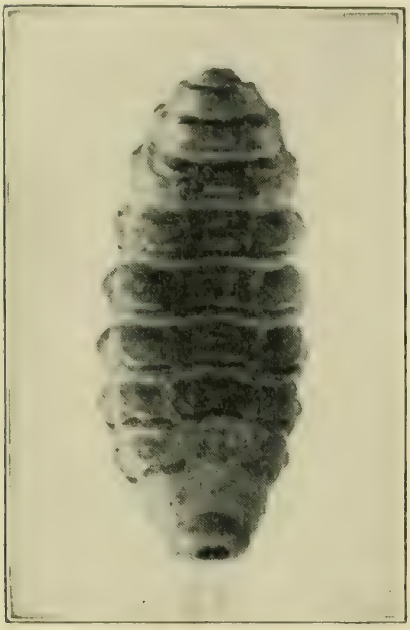


FIG. 533.—Common cattle grub or heel fly, *Hypoderma lineata* De Villiers; full-grown larva, dorsal view, about twice natural size. (*From U. S. D. A. Dept. Bull.* 1369.)

Animals Attacked.—Cattle and bison, and possibly some other wild ruminants and very rarely horses and man.

Distribution.—The heel fly is the more prevalent and widely distributed species, occurring in every state in the union. The northern ox-warble fly does not occur in the southern states but is recorded as the more common species in the northeastern states. It ranges from coast to coast in southern Canada and the northern United States.

Life History, Appearance, and Habits.—Many erroneous theories and statements about the life cycle of ox warbles are current in print and among herdsman. Consequently the true life cycle, which has now been established after more than 200 years of study, should be carefully noted. All ox warbles winter as maggots (Fig. 533), in the backs of

animals. In the latitude of Illinois the first ones begin to appear under the skin of the back in January. From that time on until April the swellings can easily be felt by passing the hand over the backs of infested cattle. The presence of the maggots causes the formation of a cyst about them, and constant irritation by the spiny maggot keeps the walls of the cyst inflamed, and the warble lives on the secretions or suppuration inside the cyst wall. Soon after reaching the back, the larva cuts a small hole through the skin through which it takes air. The maggot grows rapidly until it is about 1 inch long and very thick. When mature, it changes from white to dark brown or black, and finally squeezes its body, tail foremost, through the hole in the skin and drops to the ground,

FIG. 534.—Common cattle grub or heel fly, *Hypoderma lineata* De Villiers; male, about four times natural size. (*From U. S. D. A. Dept. Bull.* 1369.)

usually in the morning. The larvæ become mature and are leaving the back over a period of 5 or 6 months, from January to June in the North, and from November to March in the South. Having freed itself from the animal the maggot seeks protection on or in the soil, and changes through a hard-skinned pupal period, to the adult fly, which splits open the end of its case and emerges about 5 weeks later. The flies (Fig. 534), may be found about cattle from April to September although any one fly probably lives only a few days and takes no food. The earliest flies to appear are the heel fly, the northern ox-warble fly appearing a month or so later. The heel fly also disappears in midsummer, while the other species continues in the adult stage until the end of summer. In southwest Texas, Bishopp reports the heel fly as active throughout the warm periods of the winter.

The eggs of these flies are never laid on the back near the spot where the tumors appear, but mostly about the legs. The northern ox-warble fly is active chiefly on hot sunny days and is very tactless in laying its eggs. It darts at the animal with much buzzing and clings to the skin for a second while it glues an egg fast to the base of a hair. Then it retreats and in a few minutes strikes again. This quickly excites the animals though it does not seem that it could hurt them, and they throw their tails in the air and start to run wildly. The fly follows until it loses its victim in the underbrush or in water. As many as 800 eggs may be laid by one fly, one to a hair here and there over the hind legs, especially near the hock and the knee, and also on the belly. This sudden stampeding of the herd is one of the serious phases of injury by this fly and the thing which suggested the name "bomb fly." The heel fly is sneaking in its egg laying. It generally alights in the shadow near an animal, and if the animal is standing, quietly backs up and tucks its eggs among the hairs of the "heels" or, if the animal is lying down, attaches them to such hairs as it can reach along the flanks, while standing on the ground. Egg laying causes no pain and the fly is usually unnoticed, so that it may lay a dozen or more eggs on one hair in a row like the teeth of a comb (Fig. 535). In from 3 days to 1 week the eggs of either species hatch, and the minute larva crawls down the hair and bores into the skin near its base. Penetration of the skin takes several hours. It then disappears from external view at a point usually on the legs, and is next found in the region of the pharynx or œsophagus, several months later. Where it has been in the meantime can only be guessed. Animals butchered in autumn often disclose one-fourth- to one-half-grown larvæ in the walls of the œsophagus. The maggots are constantly on the move, thus avoiding the attacks of white blood corpuscles, and there is every reason to believe their visit to the œsophagus is only incidental to their general wandering about in the connective tissue of the animal's body. At the approach of winter the maggots begin to disappear from the gullet, and soon appear under the skin of the back, where growth is completed. According to Bishopp, the common cattle grub spends an average of 58 days in the larval stage after reaching the back, and the northern cattle grub an average of 73 days in this situation. There is but one generation a year.

Fig. 535.—Common cattle grub or heel fly, eggs attached to hair of a cow. (*From U. S. D. A. Dept. Bull.* 1369).

Control Measures.—It will be clear from the life cycle of ox warbles that they can most easily be attacked when the maggots are in the backs of cattle, from December to June. It should be clearly understood, however, that destroying the maggots at this time is destroying them

after they have done most of the damage that those particular individuals will do. Unless, therefore, the job is done thoroughly enough and over wide enough territory to cut down the fly population materially during the following summer, little good will result. All the stockmen over a considerable area should cooperate to make the clean-up most effective. Every animal should be gone over three or four times at intervals of 1 month, beginning in early December in the South and about the end of January in the North. The grubs may be squeezed out, pulled out with very slender forceps, or treated by rubbing into the opening to each tumor a small lump of a mixture of iodoform 1 part in vaseline 5 parts. This last method is considered best because the other methods are likely to crush the maggots and it is considered dangerous to burst them under the skin, because of the poisonous nature of their body fluids. In Denmark a pump has been used that sucks out the maggot and the pus surrounding it. If the warbles are removed mechanically they must be killed before being thrown down. No practical method of control is known for cattle on the range.

References.—U. S. Dept. Agr. Dept. Bull. 1369, 1926; *Dom. Can. Dept. Agr. Health of Animals Branch Bull.* 16, 1912; and *Sci. Ser. Bulls.* 22, 1916 and 27, 1919; *Jour. Agr. Research,* Vol. 21, pp. 439–457, 1921.

Screw Worm Fly[1]

Importance and Type of Injury.—A dark, shiny, blue-green blowfly, a half larger than the house fly, with three black stripes on the back

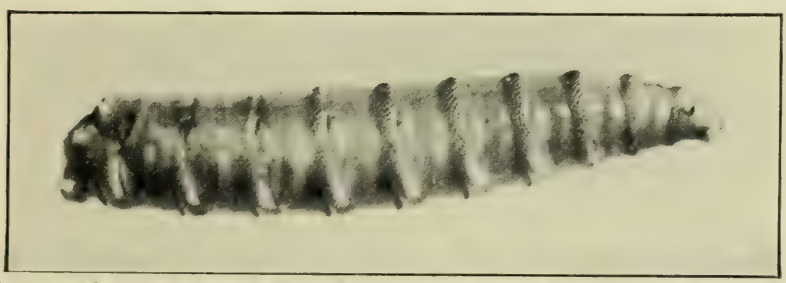


Fig. 536.—Larva of screw worm fly, side view, about four times natural size. *(From U. S. D. A. Farmers' Bull.* 857.)

between the wings, and a reddish-yellow face (Fig. 537), lays eggs in wounds on animals, such as barbed-wire cuts, scratches from fighting, blood spots where ticks or other flies have bitten the animal, brand marks, and wounds from dehorning or castrating. The maggots of these flies (Fig. 11), start to feed in the wounds, but soon invade the sound tissue, tearing it with their mouth hooks. Wounds are prevented from healing, and the sickened animal hides away in the woods or brush, refusing to eat and frequently dying if not found and treated. The habits of this fly fit it admirably to spread such diseases as anthrax,

[1] *Cochliomyia macellaria* (Fabricius), Order Diptera, Family Muscidæ.

blackleg, and hog cholera, and it is believed that such may be the case.

Animals Attacked.—Cattle, hogs, horses, mules, sheep, goats, man, dogs, and other domestic and wild animals.

Life History, Appearance, and Habits.—The overwintering stage of the screw worm is not definitely known. The adults are active throughout the winter in extreme south Texas and begin to appear on the wing from early April to mid-June farther north. They are attracted to any decaying meat or raw flesh, either the carcass of an animal that has not been buried, or a superficial wound on a living animal, in which they lay their eggs. A single female has been known to deposit over 1,200 eggs. The eggs hatch in from a few hours to a few days, and the maggots, at first

FIG. 537.—Adult of screw worm fly, *Cochliomyia macellaria* (Fabricius); about five times natural size. (*From U. S. D. A. Farmers' Bull.* 857.)

very tiny, begin plowing through the flesh, tearing and breaking it down and consuming the products. They grow very rapidly and may be ¾ inch long in 4 or 5 days, when feeding on living flesh, or in 1 to 3 weeks in carcasses. They are of typical maggot shape (Fig. 536), about ¾ inch long, white, with elevated spinose circlets at each segment, somewhat suggesting the ridges on a screw. The larva may penetrate very deeply into the flesh, but must always return to the surface to breathe through its spiracles at the large or tail end of the body. The full-grown maggots drop out of the flesh and burrow into the soil an inch or more to change from the maggot stage to the fly inside the brown seed-like skin or puparium. From a few days to 2 weeks later they are out, and soon ready to lay more eggs. It is said that a million flies may develop in the carcass of 1 cow, a generation requiring only a few weeks.

Control Measures.—Screw worm flies do not usually become serious in live stock until they have developed to unusual abundance by breeding in carcasses. The carcasses of all animals, both wild and domestic, should be completely burned or else buried deeply so that several feet of closely packed soil covers them, within a few days after death. Every precaution should be taken to avoid the injuries to animals in which the screw worms start. Dehorning, castrating, and similar operations on animals should be performed during the winter half of the year and breeding of the animals controlled so that the young are born during the same period, when flies are absent. Trapping of the adult flies is recommended in *U. S. Dept. Agr. Farmers' Bull.* 857.

If animals are infested, the wound should be treated with benzol or chloroform, the dead maggots subsequently removed, and the wound washed with a 5 per cent solution of carbolic acid in water and dressed with commercial pine-tar oil, to keep the flies away.

References.—*U. S. Dept. Agr. Farmers' Bull.* 857, 1926; *U. S. Dept. Agr. Dept. Bull.* 1472, 1927; *Jour. Agr. Research*, Vol. 31, pp. 885–888, 1925; *Jour. Econ. Entomol.* Vol. 19, pp. 536–539, 1926.

C. INSECTS ATTACKING HOGS

FIELD KEY FOR THE IDENTIFICATION OF INSECTS INJURING HOGS

A. Free-flying insects that alight on the animals to suck blood, coming and going repeatedly:

1. Flies of the size and appearance of the house fly, often cluster about the ears and in other places on the body and suck blood from the animals, causing much pain. They can be recognized by the slender, stiff beak that projects forward from the lower side of the head; by the broad abdomen, that is gray with four to six black spots; and by the palps, that are less than half as long as the beak. *Stable fly*, page 802.

2. Heavy-bodied, swift, brownish to black flies, ½ to 1 inch long, with two clear or banded wings, alight on animals and suck their blood, usually leaving a drop or two of blood exuding from the puncture. Especially troublesome about marshes, swampy woods, or meadows, and on warm sunny days. *Horseflies*, page 768.

3. Very small, stout, black flies, less than ⅙ inch long, with a humped thorax, thick, 11-segmented antennæ as long as the head, two broad, delicately veined wings, and stout legs, pierce the skin and suck the blood especially about the eyes, ears, and nostrils, causing extreme pain. *Black flies, turkey gnats* or *buffalo gnats*, page 832.

B. Wingless insects that crawl or jump upon the body to bite and suck blood, but do not spend their entire lives on the animal:

1. Small, brown, wingless insects, about 1/16 inch long, very flat from side to side and with long hind legs, jump vigorously when disturbed. *Cat flea, dog flea, human flea*, and others, page 839.

C. Wingless insects that stay on the animals all of the time:

1. Hogs rub and scratch. Large, flattened, grayish, wingless lice, up to ¼ inch long, with head, thorax, abdomen, and legs bordered with black; head and legs long, the latter with a peculiar hook at the end to clasp about hairs; mouth parts withdrawn into the head when not sucking blood; especially abundant in folds of the skin. The large, yellowish-white eggs are glued to the hairs on lower half of body. The only louse of the hog. *Hog louse*, 798.

2. Hogs rub vigorously. The hair stands erect, the skin about the ears, on top of the neck, on the withers, and down the back to the base of the tail becomes cracked and scabby. Caused by minute, short-legged, rounded mites, just big enough to be seen, that burrow into the skin. *Mange mite*, page 800.

3. Tender skin about muzzle, eyes, or inner side of legs forms small hard pimples from the size of a pinhead to that of a small marble, which are filled with a yellowish pus. *Follicle mites*, page 801.

C. *Spiny worms or maggots that live in the flesh of wounds:*

1. Slender, whitish maggots, up to 3/4 inch long, blunt behind and tapering to a point in front, with elevated spiny rings about the segments giving them a screw-like appearance, burrow into the flesh of wounds and abrasions or into the body through its natural openings. The eggs are laid in scratches, wounds, or natural body openings by a dark, bluish-green fly, about 3/8 inch long, with three black stripes on thorax and a reddish face. *Screw worm fly*, pages 795 and 802.

So far as its insect parasites are concerned, the hog sustains its reputation of being a hardy and healthy animal. It has only two serious insect parasites, the hog louse and the mange mite, besides which it is attacked to some extent by several kinds of flies.

Hog Louse[1]

Importance and Type of Injury.—The only louse found on the body of hogs is a blood-sucking louse (Fig. 538), very similar in appearance to the short-nosed cattle louse, but about twice as large when mature. It reaches a length of nearly 1/4 inch, and is the largest blood-sucking louse found on any farm animal. On account of its size, it is easily seen, although its color is a dirty gray-brown, almost matching the skin of the hog. The margins of the body and appendages are bordered with black. The lice torment the hogs by piercing the skin to suck the blood. This causes the animals to rub vigorously against feed troughs and fences and to scratch with their feet. The skin becomes thick, cracked, tender, and sore, the animals restless and unprofitable.

Animals Attacked.—Hog lice do not infest other kinds of live stock.

Life History, Appearance, and Habits.—The lice (Fig. 538), are most noticeable on hogs in cold weather. In winter they usually cluster in small clumps on the inside of the ears or in folds of skin about the neck or on the inside of the upper part of the legs. Big and little together, they cling to the hairs by their legs, which are adapted to clamp about the hair very securely. They feed frequently, puncturing the skin each time with very slender stylets, which are completely withdrawn into the head when not feeding. Egg laying goes on all winter long, a female laying from three to six eggs a day, gluing each fast to a hair close to the skin. The eggs (Fig. 538) are big enough to be seen, elongate, the smaller end glued by one side to the hair, the other end with a rounded cap. They are whitish in color when fresh, but after a few days become stained yellow

[1] *Hæmatopinus suis* (Linné), Order Anoplura, Family Hæmatopinidæ.

or brownish. Most of the eggs are found on the lower half of the body. In 2 or 3 weeks the small louse pushes off the cap of the eggs, seeks a tender place on the skin and sucks blood until satisfied. It then withdraws its mouth parts and soon bites in another place. The young are of the same shape as the adults, but pale-colored. In 2 weeks, during which time they molt three times, they are full-grown, and mating and egg laying begin at once. The females live about 5 weeks, during the last 3 of which they lay eggs almost every day. There are probably six to a dozen or more generations a year. All stages are passed on the host. The lice never voluntarily leave a hog except when they can crawl directly upon the body of another hog. If dislodged from the animal they rarely live more than 3 days.

FIG. 538.—Female hog louse, *Hæmatopinus suis* (Linné), and egg attached to hair. About six times natural size. (*From U. S. D. A. Farmers' Bull.* 1085.)

Control Measures.—Where the number of hogs in the herd is not too large, the best method of treatment is to apply a thin even coat of oil all over their bodies with a fine-bristled brush. Especial attention should be given to the inside of the ears, the folds of the skin about the neck and the inner surface of the thighs, to be sure that all eggs are wet with the oil. Any of the following mixtures is satisfactory: (*a*) crude petroleum, (*b*) raw linseed oil, (*c*) half and half kerosene and lard, or (*d*) equal parts kerosene and cottonseed oil. Every animal in the herd should be treated and again in 2 weeks. Hogs must be kept out of the sun and not driven or excited, for a day after oiling. A simple and effective method of treatment is to apply crude oil or used crank-case oil directly to the hogs by means of a sprinkling can. Two or three applications should be made at intervals of 2 or 3 weeks.

If animals cannot be treated by hand, they should be dipped in natural crude petroleum or the processed fuel oil or in one of the com-

mercial coal-tar-creosote dips. Suggestions for dipping and detailed plans for a dipping vat are given in *U. S. Dept. Agr. Farmers' Bull.* 1085. The Department of Agriculture recommends the construction of cement hog wallows to contain 3 or 4 inches of water, to which is to be added once a week a quart of crude petroleum for each hog. A day or two after each application of oil, the wallow is drained and the hogs are given water without oil the rest of the week. A 1 per cent solution of pine tar in water may be used instead of the petroleum on water. Such a wallow should be built in a shady place, all other wallows done away with, and the oil added in the evening, and not until the hogs are accustomed to using the wallow with water alone.

The so-called hog oilers, consisting of an oil-saturated fabric of some kind, wrapped about a post, or commercial metal hog oilers against which the hog may rub and so wet its skin with oil, cannot treat the parts of the body worst infested. The lice cannot live off the host more than a few days, and do not breed in the bedding.

References.—U. S. Dept. Agr. Farmers' Bull. 1085, 1920; *Tenn. Agr. Exp. Sta. Bull.* 120, 1918.

Mange Mites[1]

When hogs are scratching and rubbing vigorously, if an examination does not reveal the large gray hog lice it is probable that the animals are infested with mange mites (Fig. 539). If the skin about the eyes, ears, and along the top of the neck and back is inflamed, scurfy, scabby, with small pimples, or cracked and raw, scrapings from the skin should be made. It is necessary to scrape with a dull knife until the blood starts, to get the mites out of their burrows. Spread the scrapings out over some dark surface and examine under a hand lens or magnifying glass, in a warm place. If minute, pale-colored, nearly-round, eight-legged mites (Fig. 525) are found crawling among the scrapings, the hog is infested with common mange, which is further discussed under the insects attacking horses.

Control Measures.—The control of mange is the same as for hog lice, but very thorough applications are necessary. One dipping in crude petroleum is said to eradicate both lice and mange. Mange is very contagious, and all animals in the herd should be treated, whether they seem to be infested or not. Healthy animals must be kept so that they cannot touch infested ones until the latter are treated, and pens harboring infested animals must be disinfected, since the mites or their eggs may live off the animal for several weeks.

Reference.—U. S. Dept. Agr. Farmers' Bull. 1085, 1920.

[1] *Sarcoptes scabiei suis* Gerlach, Order Acarina, Family Sarcoptidæ.

Follicle Mites

Sometimes hogs become infested with another kind of mite[1] which lives in the hair follicles about the muzzle, eyes, base of tail, or on the tender skin on the inner sides of the legs. The skin becomes red and inflamed, and small hard pimples ranging in size from that of a pinhead to lumps as big as a small marble form and break, discharging a yellowish cheesy pus. The trouble is caused by a very minute, slender, worm-like mite, with four pairs of very short legs.

Fig. 539.—A severe case of hog mange, showing pimple-like scabs caused by the mites. (*From U. S. D. A. Farmers' Bull.* 1085.)

Animals Attacked.—Cattle, dogs, hogs, and man are affected.

Control Measures.—On account of the fact that the mites burrow so deeply in the skin, there is no practical way to cure an infested herd. Badly infested animals should be killed, the others fattened for butchering and disposed of as soon as practicable. The premises should be disinfected with a 1- to-15 lime-sulfur spray, kerosene emulsion, or one of the commercial dips, before restocking with healthy hogs.

[1] *Demodex phylloides* Csokor or *Demodex folliculorum suis*, Order Acarina, Family Demodicidæ.

Flies

The stable fly (Fig. 522), bites hogs severely about the head and ears or at cracks or scratches in the skin. Besides the controls given on page 772, a deep, dusty furrow in which hogs may lie should be provided. Horseflies, (Fig. 521), black flies, (Fig. 551), and mosquitoes also bite hogs when abundant. These pests are discussed under Horses and Cattle. The screw worm fly, (Fig. 537) attacks all kinds of wounds, scratches, and sores on hogs, laying its eggs in them, and the maggots invade the sound flesh and prevent the wound from healing. Treatment is the same as given under Cattle.

Fleas

These well-known little pests (Fig. 555), often increase to great numbers about hog lots, doubtless making life very uncomfortable for the hogs, as they do also for any persons who come near. Mules and horses kept near infested hog lots are often annoyed. Cleaning up the litter and spraying with creosote oil give an effective cleanup, according to Bishopp. Fleas are further discussed as pests of man, page 839.

D. INSECTS AFFECTING SHEEP AND GOATS

FIELD TABLE FOR THE IDENTIFICATION OF INSECTS INJURING SHEEP AND GOATS

A. Free-flying insects that alight on the animals to suck blood, coming and going repeatedly:

1. Flies of the size and general appearance of the house fly suck blood especially from the legs, causing the animals to stamp their feet. Distinguished from the house fly by its stiff, slender beak, sticking straight forward from the under side of the head, by its broader black-spotted abdomen and grayer appearance, and by the bristle on antenna having hairs on its upper side only. Palps less than half as long as proboscis. Usually rests with its head upward. *Stable fly*, page 770.

2. Very small, stout, black flies, less than $\frac{1}{6}$ inch long, with a humped thorax, thick, 11-segmented antennæ, as long as the head, two broad, delicately veined wings, and stout legs, pierce the skin and suck the blood, especially about the eyes, ears, and nostrils, causing extreme pain. *Black flies* or *buffalo gnats*, page 832.

B. Insects that stay on the animal all of the time:

1. Chestnut-brown, wingless, flattened, tick-like insects about $\frac{1}{4}$ inch long, with a leathery spiny skin, a sack-like, unsegmented abdomen, short head, and six tapering, wide-spread legs, cling to the skin beneath the wool and suck blood. Often very severe on lambs. No exposed egg or larval stage; the rounded, brownish, ovate puparia, about $\frac{1}{8}$ inch across, are often wrongly called "nits." The maggots are born full-grown and glued to the wool, especially about the neck. *Sheep tick*, *louse fly* or *ked*, page 803.

2. The wool comes out in patches, "tagging" to weeds, fences, etc., on which the animals rub, leaving bare, scabby places on the skin. Under these scabs may be found thousands of minute, eight-legged, oval-bodied mites, just visible to the naked eye, which pierce the skin with their mouth parts, causing an exudation that hardens over them as a scab. They do not burrow into the skin. *Scab mite*, page 805.

3. A very small, brownish louse with a broad red head, only about $\frac{1}{20}$ inch long, is found among the wool and on the skin of sheep, causing them to rub and scratch. *Red-headed sheep louse*, page 807.

4. A louse up to $\frac{1}{12}$ inch long, the body tapering toward the front, the head as broad as long, and two transverse rows of hairs on each abdominal segment, is found

among the short coarse hairs of the legs below the true wool. *Blood-sucking foot louse*, page 807.

5. About the same size and appearance as *B*, 4, but occurs over entire body and face under the wool, sometimes in clusters. Slightly more slender than the foot louse, and the head twice as long as broad. Wool about the clusters of lice generally discolored by the small pellets of excrement. *Blood-sucking body louse*, page 807.

C. Maggots that live in the bony cavities of the head or under the wool or in sores:

1. Animals are nervous, push their noses between other sheep or into the dust, paw with their feet, shake their heads, run with heads held low, and sneeze. There is a copious, foul discharge from the nostrils. This trouble is caused by a grayish-brown fly, about ½ inch long, which deposits small, active maggots in the nostrils. The maggots work upward through the nostrils and then tunnel through the nasal and frontal sinuses, frequently causing death. These larvæ are fleshy, creamy white, and brownish banded, finally reaching a length of about 1 inch. "*Grub-in-the-head*," "*staggers*," *sheep bot* or *sheep nose fly*, page 808.

2. Slender, whitish maggots, blunt behind, tapering in front, up to ¾ inch long, burrow in matted, soiled wool, or into the flesh, especially at points injured by "ticks" or other piercing insects or by dogs. Eggs are laid by a brilliant green or a blue, metallic fly, larger than the house fly, about ⅜ inch long. *Green-bottle fly*, *screw worm fly* or *black blowfly*, page 810.

General References.—"Parasites and Parasitic Diseases of Sheep," *U. S. Dept. Agr. Farmers' Bull.* 1150, 1920; "Insect Parasites of Goats in the United States," *National Angora Record Jour.* Vol. 1, No. 1, September, 1922.

Sheep Tick, Louse Fly, or Ked[1]

Importance and Type of Injury.—The sheep "tick" (Fig. 540), is one of the most remarkable insects known. It is not a tick, like the Texas-fever tick or spotted-fever tick, but is a degenerate louse-like fly that has completely lost its wings. It crawls about over the skin among the wool and feeds by thrusting its sharp mouth parts into the flesh and sucking blood. It causes sheep to rub, bite and scratch at the wool, thus spoiling the fleece; and, when abundant, the animals are unthrifty and unprofitable. Estimates by a large number of sheep owners some years ago indicate that the presence of this insect causes a loss amounting to 20 to 25 cents a head a year on the average in weight and wool production. If this estimate is correct, the sheep tick taxes the sheep industry of this country several million dollars a year on the approximately 40,000,000 head of sheep kept by American farmers. They are especially severe on lambs, to which they migrate readily from the ewes.

Animals Attacked.—Sheep only.

Distribution.—Nearly cosmopolitan.

Life History, Appearance, and Habits.—The second remarkable thing about the sheep tick is its method of reproduction. Unlike true ticks, which always drop to the ground to lay eggs, the sheep tick spends its whole life on the animals. Two life stages are commonly found on sheep at any season of the year. The adults (Fig. 540), which are brown,

[1] *Melophagus ovinus* Linné, Order Diptera, Family Hippoboscidæ.

wingless, and six-legged, have a broad, leathery, unsegmented, sac-like abdomen. The thorax is small, the legs widespread, the first pair appear to come out at the sides of the head. The body is about 1/4 inch long, and covered with short, spiny hairs. The other exposed stage of the sheep tick is the so-called "nits." These (Fig. 540), are nearly round, chestnut brown, egg-like objects that are glued fast to the hair, especially about the neck, inside of thighs, and along the belly. They are not eggs, but pupa cases or puparia enclosing the pupal stage of the fly. The sheep tick does not lay its eggs. The maggots are nourished within the body of the female until they are full-grown, never feeding externally. When born they are whitish in color, oval, about 1/8 inch long, and without appendages. The female secretes a gelatinous glue which sticks

FIG. 540.—The sheep tick or louse fly, *Melophagus ovinus* Linné. Puparium on the left; adult fly on the right. Four and one-half times natural size. (*From Herms, "Medical and Veterinary Entomology, copyright,* 1923, *by The Macmillan Company. Reprinted by permission.*)

the larva to the hair. Within 12 hours the skin turns brown and forms a hard puparium about the larva. Within this case, pupation takes place and, in summer, the adult tick breaks out of its puparium from 19 to 23 days after it was born. In cold weather 3 to 5 weeks, or even longer, may be spent in the puparium. After emerging, the adults may mate in 3 or 4 days, or not for several months. After mating, the females begin depositing full-grown larvæ in from 14 to 30 days. Only one young is developed at a time, and each female produces from 10 to 20 maggots, which are born at the rate of about one a week. The female may live as long as 5 or 6 months. Sheep ticks never normally leave their hosts. If separated from the animal, they may live for a week or slightly longer, but most of them die in 3 or 4 days. The pupæ, however, may live 1 or 2 months apart from the host, in warm weather. Freezing kills this stage. Breeding is continuous, though slower in winter, and there are probably several generations a year.

Control Measures.—The best control for sheep ticks is to dip the sheep in early fall in one of the coal-tar-creosote dips used according to directions

furnished with the materials. No dip which can be used will kill all the pupæ. Still, it is possible by carefully timing the dips, completely to eradicate the ticks in two dippings, 24 days apart, in warm weather. The cost of dipping should not exceed a few cents a head for each treatment. Dipping cannot be done in cold weather. If sheep have not been dipped in fall, and ticks become abundant in winter, they may be checked by several dustings of pyrethrum powder sifted into the wool. Since the ticks may crawl a considerable distance in search of animals, it is not wise to leave wool that has been sheared near the flock. It should be stored at least 50 feet away.

References.—*U. S. Dept. Agr. Farmers' Bull.* 798, 1917; *Wyo. Agr. Exp. Sta. Bulls.* 99, 1913 and 105, 1915.

Scab Mite[1]

Importance and Type of Injury.—One of the most injurious and contagious of sheep diseases is the trouble known as scab or scabies. It is first indicated by "tagging," that is the loss of bits of wool on weeds, fences, and other objects against which the animal has rubbed its body (Fig. 542). The cause of this tagging or loss of hair is a very small, eight-legged mite, that punctures the skin with its sharp mouth parts until the lymph exudes and flows over it. As this serum hardens to form a scab, the mites remain underneath on the raw skin where their continued feeding results in successive layers of scabs that eventually lift the hair out by the roots. The irritation and loss of blood due to the mites, and probably some poison introduced as they feed, cause the sheep to lose condition, become sickly and, if not treated, to die. In less severe cases the loss of wool is a considerable item. The skin becomes first reddened, then white and glistening, then hardened and uniformly thickened over the infested part, and eventually bare of wool, cracked, and bleeding.

Animals Attacked.—Sheep and cattle suffer most, while horses and goats are attacked rarely. Fine-wooled varieties of sheep are most seriously affected.

Distribution.—Nearly cosmopolitan; but quarantines and dipping campaigns have eradicated it from many sections.

Life History, Appearance, and Habits.—All stages of the scab mite will be found upon lifting a scab from an infested animal, the eggs, young, and adults swarming together under this protection. The largest mites (Fig. 541), are only as big as the cross-section of an ordinary pin or needle, and may be seen as minute gray crawling specks against a black surface. A dozen or more of eggs are laid by the female on the skin. They hatch in 2 to 10 days to six-legged nymphs. After the skin is shed the first time,

[1] *Psoroptes communis ovis* Hering, Order Acarina, Family Sarcoptidæ.

the nymphs have an additional pair of legs. They grow rapidly and are mature in from 9 days to 2 weeks. A female may live 1 month or more and deposit up to 100 eggs. In wet, cold weather, generations succeed each other rapidly; the mites spread from sheep to sheep and whole flocks are soon affected.

Control Measures.—For a number of years, quarantine measures have been in effect against the shipment of scabby sheep, and the disease has

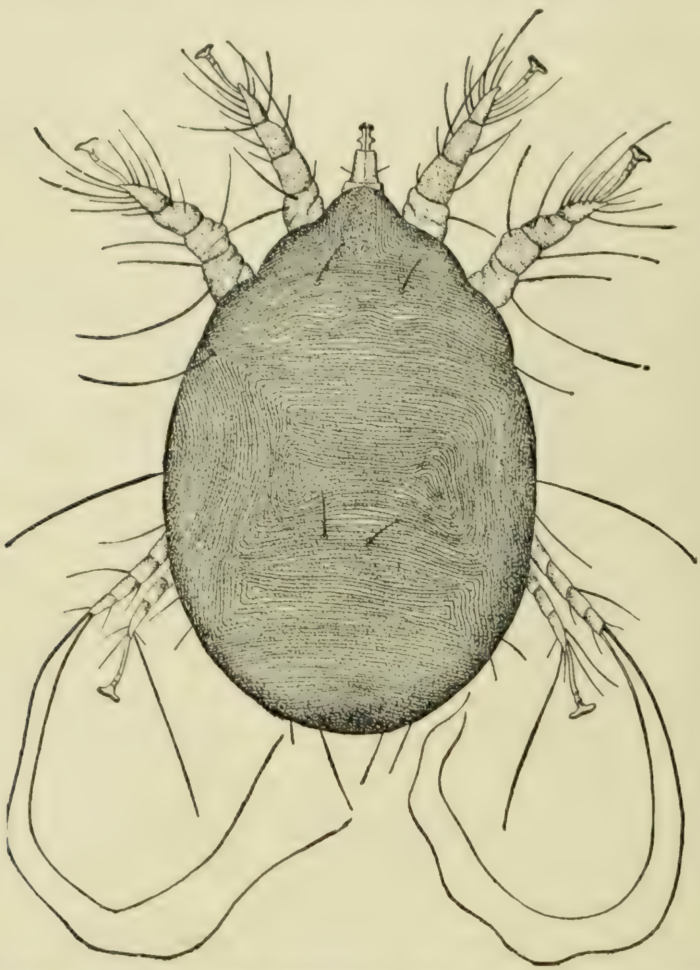


FIG. 541.—The scab mite, *Psoroptes communis ovis* Hering, female, greatly magnified. (*From U. S. D. A. Farmers' Bull.* 713.)

been greatly reduced in prevalence. Control is by dipping the animals for 3 to 5 minutes in a warm lime-sulfur, or nicotine-and-sulfur, dip, and repeating the treatment once or twice at 10- to 14-day intervals. Directions for dipping sheep are given in *U. S. Dept. Agr. Farmers' Bull.* 713, which should be consulted before dipping is undertaken. The quarters occupied by the infected sheep must be thoroughly disinfected by cleaning and spraying with 5 per cent carbolic acid, or lime-sulfur or creosote dips, and the animals should be changed to fresh pasture.

Reference.—U. S. Dept. Agr. Farmers' Bull. 713, 1916.

Sheep Lice

Importance and Type of Injury.—Three species of lice are known to live on sheep in this country: the blood-sucking body louse,[1] the blood-sucking foot louse,[2] and the red-headed or chewing sheep louse.[3] They are by no means as prevalent as the sheep tick. The usual symptoms of scratching and rubbing are caused by these lice biting and running over the skin. The chewing louse eats off the wool fibers, the blood-sucking

Fig. 542.—A severe case of sheep scab due to the attacks of the scab mite. (*From U. S. D. A. Bur. Animal Industry.*)

kinds rob the host of nutrition and the blood-sucking body louse stains the wool with its small brown fecal spots. The red-headed sheep louse is said to be the most irritating, and the foot louse to be comparatively innocuous.

Life History, Appearance, and Habits.—The red-headed sheep louse is the smallest and apparently the worst of the three species. It is only $\frac{1}{20}$

[1] *Linognathus ovillus* (Neumann), Order Anoplura, Family Hæmatopinidæ.

[2] *Linognathus pedalis* (Osborn), Order Anoplura, Family Hæmatopinidæ.

[3] *Trichodectes ovis* Linné, Order Mallophaga, Family Trichodectidæ.

inch long, pale brownish in color, with a broad, reddish head, broadly rounded in front. Each segment of the abdomen has a single transverse row of hairs. These lice crawl about among the wool and on the skin, eating wool fibers and skin scales. They do not suck blood, but when they cluster on the skin in great numbers may cause raw sores. The blood-sucking foot louse is similar in form to the short-nosed cattle louse but only about $\frac{1}{12}$ inch long and somewhat slenderer and paler colored. The head is about as wide as long, and each abdominal segment has two transverse rows of hairs. The blood-sucking body louse is similar to the foot louse, but the head is twice as long as broad and bluntly pointed in front. All of these lice spend all stages, eggs, nymphs of various sizes, and adults, on the body of the animal. The eggs are glued fast to the hairs, and hatch in 5 to 10 days in the case of the chewing louse, or 10 to 18 days in the other species. The young are said to complete growth and begin laying eggs in about 2 weeks after hatching.

Control Measures.—All kinds of lice are best killed by dipping the animals in nicotine, sulfur, or creosote dips, giving two treatments 2 weeks apart. The red-headed sheep louse may be controlled by dusting sodium fluoride into the wool all over the animal. A plunger-type duster should be used, and about 1 ounce is sufficient for each sheep. This stomach poison is not effective for blood-sucking lice. In winter, when dipping cannot be done safely, the lice may be checked by dusting pyrethrum or derris into the wool. Shallow dipping or washing of the legs in nicotine, sulfur, or creosote dips should be sufficient for the foot louse and this can be done at any season. All new animals should be examined before they are turned into a healthy flock, and especial attention should be given to males, which often infect a flock of ewes at breeding time.

Sheep Bot or Nose Fly[1]

Importance and Type of Injury.—Sheep shake their heads, stamp their feet, and crowd together, holding their noses to the ground, especially in bare dusty places; or run away, with noses held low, in efforts to keep the fly from striking at their nostrils. The presence of the maggots in the nostrils causes inflammation, and a copious "catarrhal" discharge. The excess of mucus, together with irritating dust drawn into the air passages, causes sneezing and labored breathing. The presence of the maggots may cause giddiness or "blind staggers."

Animals Attacked.—Sheep, goats, wild deer, and, very rarely, man.

Distribution.—General throughout North America.

Life History, Appearance, and Habits.—The life history of this fly appears not to be well known. Hadwen has found both small and full-grown maggots in the heads of sheep both in winter and in summer, indi-

[1] *Œstris ovis* Linné, Order Diptera, Family Œstridæ.

cating that the larvæ may remain in the head for more than a year. Portchinsky, working in Russia, states that the larvæ pass the winter in the second instar in a state of rest with little change, forming the third- and last-stage larvæ in spring. The full-grown larva, is nearly 1 inch long by a third as thick, without definite head or legs, and the segments prominently marked with blackish crossbands. Probably the typical cycle is for different larvæ to become mature from early spring to late summer, when they retreat from the deeper tunnels they have made, and drop or are sneezed out of the nostrils to the ground. Here a transformation period of 30 to 60 days is passed in the hard, blackish puparia before the

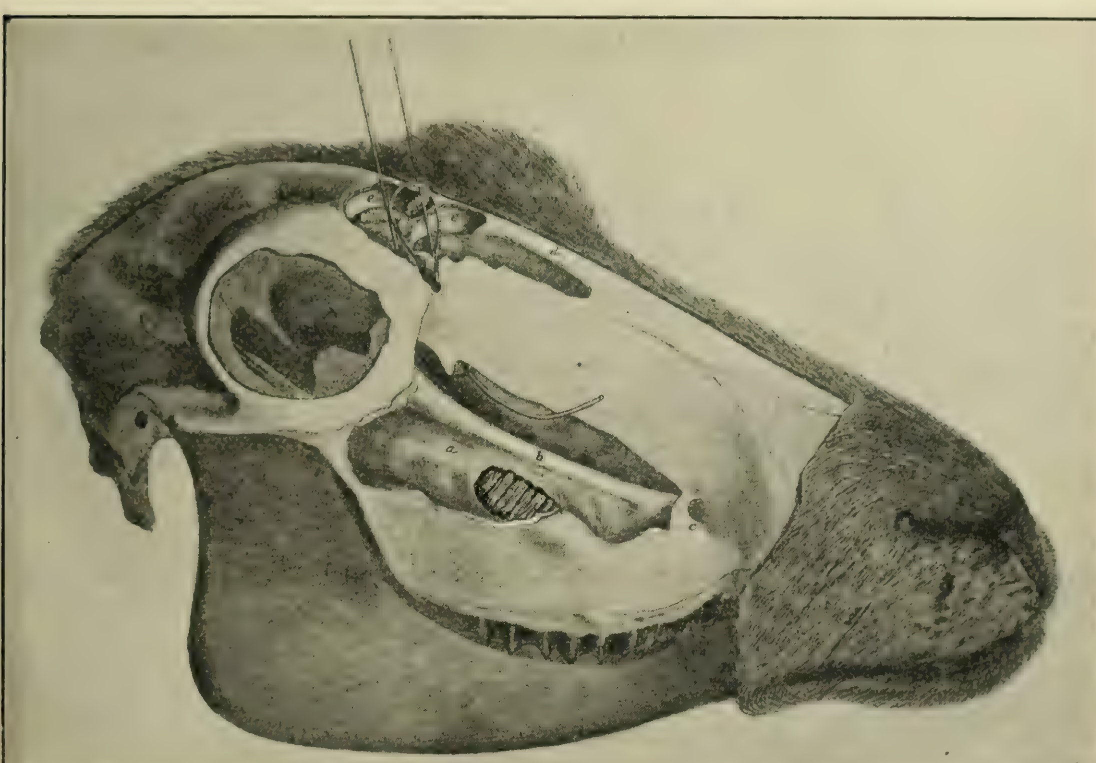


Fig. 543.—Sheep botfly, larvæ (at *a* and *e e*) tunneling through sinuses of sheep's head. (*From U. S. D. A. Bur. Animal Industry.*)

flies emerge. Some of the flies are apparently active until cold weather approaches. They are about ½ inch long, of a general grayish color, something like a house fly but much larger, with minute dark spots peppered over the back and with eyes rather small and a broad space between them. They take no food, but follow sheep on hot, still, sunny days and hide away in crevices of fences and walls in inclement weather. The eggs hatch in the body of the female, before they are laid and a number of very active, small maggots, enclosed in a little drop of sticky liquid, are deposited up the nostrils, as the female flies rapidly past the sheep's head without alighting. The maggots work their way upward through the nostrils until they reach the sinus cavities between the bony plates of the skull in the region of the forehead (Fig. 543). In other cases

they find their way into the bronchi or into cavities in the horns or bones of the nose or jaw. They lacerate the tissues, growing slowly and sometimes migrating far about in the head. As many as 80 larvæ have been reported from one head, but the usual number is from 1 to 8. They remain in the head for about 10 months or more.

Control Measures.—To prevent infestation by the sheep bot, the nostrils may be kept smeared with pine tar. The sheep may be made to smear their own noses by an ingenious salt log, in which salt is placed in the bottom of 2-inch holes bored in the log and the edges of the holes smeared with pine tar. Hadwen recommends the provision of a dark shed with a curtain over the door, into which the sheep may retreat when the flies begin to attack them. It has been recommended that infested sheep be treated by elevating the head and pouring into one nostril at a time a teaspoonful of benzene, holding that nostril shut for half a minute and then treating the other nostril. The treatment may have to be repeated several times to get all of the maggots and is of doubtful value and may be dangerous to the sheep. Portchinsky recommends, as the only effective measure, the capture of adult flies which are attracted to erect fences or screens of old weathered boards and may easily be picked off mornings, evenings, and in bad weather. A skilled veterinarian may remove larvæ from the heads of valuable animals by opening the sinuses above the nasal fossæ with a trephine.

Sheep Maggots or Wool Maggots

Importance and Type of Injury.—When the wool of sheep becomes soggy from warm rains, or soiled with urine, feces, or blood from wounds or from lambing, certain blowflies are attracted to the animal and deposit their eggs in the dirty wool, most commonly about the rump, but also about the horns where wounds have resulted from fighting. The maggots feed in the wet wool and the adjacent skin, causing the latter to fester and the wool to loosen and become putrid, and exposing the inflamed, raw flesh with the whitish maggots tunneling in it. The dirty wounds readily become infected and the sheep may die of blood poisoning.

Animals Attacked.—Sheep, goats, cattle, and other animals if they have putrid sores. Greasy, fine-wooled sheep such as Merinos are more likely to be infested.

Life History, Appearance, and Habits.—There are several kinds of flies that attack soiled wool, but two of the most important are the green-bottle fly[1] and the black blowfly.[2] The first species is about twice the bulk of the common house fly and of a brilliant metallic, bluish-green color with bronze reflections, without stripes, and with a fine whitish bloom on the front of the thorax just behind the head. The black blowfly is a little larger, very dark greenish black in color all over, without stripes or grayish markings and not very bristly. Both of these flies probably winter as larvæ or pupæ in soil beneath carcasses, or in manure. At any rate the flies appear very early in spring, and from that time on, breeding is continuous except as checked by dry weather. The larvæ of the black blowfly are said to live chiefly in carcasses or carrion; the green-bottle fly develops also in garbage.

[1] *Lucilia sericata* Meigen, Order Diptera, Family Muscidæ.

[2] *Phormia regina* Meigen, Order Diptera, Family Muscidæ.

Either fly may complete a generation from egg to egg in about 3 weeks. Their numbers increase as the season progresses, and during warm, rainy, or foggy weather they are especially likely to lay eggs in the wool. The pupa stage is passed in the ground.

Control Measures.—Since the flies attack animals chiefly after having become abundant by breeding in carcasses, the control measures are, as for the screw worm fly, to destroy all carrion by promptly burning it or burying it deeply. Breeding hornless sheep; having the lambs come as early in spring as practicable; shearing before lambing occurs; docking of lambs; "tagging" dirty sheep; and applying pine tar to wounds are recommended as preventive measures. When sheep are infested, the wool should be clipped close around the infested area, benzol or chloroform applied to the affected area, the maggots removed, and the wounds treated with copper sulfate or air-slaked lime, to dry up the suppuration and deodorize the wounds.

Reference.—U. S. Dept. Agr. Farmers' Bull. 857, 1922.

True Ticks

Although several species of ticks may attach to sheep to feed, they are not so injurious to sheep as to the less hairy animals. In fact, pasturing infested ground with sheep has been suggested as a control for ticks, since the latter may become entangled in the wool and killed. However, at least two species of ticks are injurious to sheep. The spotted-fever tick, which is discussed as a pest of man, p. 842 causes a kind of paralysis in sheep by biting and engorging along the backbone. The removal of the large female ticks from the head, neck, and back, by hand, or the use of an arsenical dip results in rapid recovery from the disease. The spinose ear tick (p. 791) also attacks sheep, feeding especially inside the outer ear.

The lone star tick[1] is very troublesome to goats, especially in the southwest.

E. INSECTS THAT ATTACK POULTRY

FIELD KEY FOR THE IDENTIFICATION OF INSECTS INJURING POULTRY

A. Pests that visit the fowls only to secure food, coming and going repeatedly; or live on the fowls at night, hiding away in the daytime; or spend only part of the life-cycle on the fowls, being free-living or intermittent parasites during other life stages:

1. Small, gnat-like, humpbacked flies, less than $\frac{1}{6}$ inch long, with thick antennæ, as long as the head; two, broad, delicate wings and stout legs, hover about the heads of fowls on the roost, suck blood, and appear to smother the birds when very abundant in spring. *Black flies, turkey gnats*, or *buffalo gnats*, page 832.

2. Mahogany-brown, broad, very flat or thin, oval, wingless bugs, of all sizes up to $\frac{1}{5}$ inch long, live in nests, behind boards, and in cracks of houses during the daytime, and crawl out upon fowls at night and suck blood. Bugs have a bad odor. Small black spots of excreta from the bugs often seen on the eggs and about cracks. *Bedbug*, page 836.

3. Small, grayish to dark red, pear-shaped or ovate mites, from $\frac{1}{20}$ to $\frac{1}{40}$ inch long, with eight slender legs, remain in cracks under the roosts or in nest boxes during the day, except on sitting or laying hens in dark places. At night they swarm over the birds and suck the blood. *Poultry mite* or *roost mite*, page 813.

4. Similar to the poultry mite but females with tip of body slightly notched. The mites live on the fowls day and night, laying their eggs among the fluff feathers. Nymphs and adults suck blood. *Feather mite* or *tropical fowl mite*, page 815.

5. In the South, poultry are attacked by a larger, eight-legged, oval-bodied, brown tick, up to $\frac{1}{3}$ inch long, which in the adult stage attacks the host only at night,

[1] *Amblyomma americanum* (Linné), Order Acarina, Family Ixodidæ.

when it sucks blood in quantities, and hides in cracks during the day like the poultry mite. In its younger stages, however, it is a permanent parasite, remaining on the fowl day and night until ready to molt. *Fowl tick, adobe tick* or *bluebug*, page 816.

6. A tiny, hard, long-legged, jumping insect, about $^1/_{20}$ inch long and flattened from side to side; the females attach to, or burrow into, the skin about the eyes, comb, wattles, or vent in clusters, often forming dark areas visible from some distance; ulcers, blindness, and death, especially of young chicks, often result. Immature stages are passed in cracks of the henhouse or in the soil. A southern species. *Sticktight*, or *southern chicken flea*, page 817.

B. Small, wingless, flattened chewing lice that stay on the skin or feathers of the fowls all of the time:

1. Ovate, yellow lice, less than $^1/_{16}$ inch long, with a single transverse row of hairs on each abdominal segment, above. Found along the shafts of the feathers of chickens rather than on the skin; when the feathers are parted, they run toward the body along the shaft. Chew at the feathers. Eggs glued to base of feathers. Not on young chicks. *Small body louse* or *shaft louse*, page 820.

2. Similar lice, form $^1/_{10}$ to $^1/_8$ inch long, darker yellow and more hairy; the hairs on upper side of abdomen in two transverse rows on each segment. Found running rapidly over the skin of chickens, turkeys, and pheasants in less feathered parts; not on the feathers. The most injurious species on grown chickens. Eggs attached especially to small feathers below the vent. *Large body louse*, page 817.

3. Lice about the size of the shaft louse, but dark grayish in color and with a longer head, found standing on their heads among the feathers of the head on chickens; move but little. Hairs on upper side of abdomen mostly confined to a wide median stripe. Antennæ of male unusually large. The most injurious louse to young chicks. Eggs laid singly on the down of the head. *Head louse*, page 817.

4. Similar to the head louse but more slender and darker in color. The only species found commonly on the large wing feathers of chickens, where it often lies between the barbules on the under side of the shaft, showing no signs of life. Eggs between barbules of large feathers. *Wing louse* or *variable louse, Lipeurus variabilis* Nitzsch.

5. A very large species, $^1/_8$ inch long and more than half as wide. Smoky gray to black in color; found on feathers on chickens and very active. Not common. *Large chicken louse, Goniocotes abdominalis* Piaget.

6. A large chewing-louse, $^1/_8$ inch long, with each hind angle of the head prolonged into a sharp process, at the end of which is a very long bristle; occurs on the feathers of the turkey, especially on the neck and breast. *Large turkey louse, Goniodes stylifer* Nitzsch.

7. A louse of equal length with the preceding, but only one-sixth as wide as long; pale yellowish, with a black margin around the body; especially common on the primary wing feathers of turkeys. *Slender turkey louse, Lipeurus polytrapezius* Nitzsch.

8. A small species only $^1/_{25}$ inch long, with head curiously expanded and rounded in front; dark red in color, with a white region in middle of abdomen; is common at the base of the large wing feathers of ducks and geese. *Chewing louse of ducks and geese, Docophorus icterodes* Nitzsch.

9. A larger species, $^1/_6$ inch long, and slender, light yellow in color with a dark margin to the body, and squarish dark spots on the abdomen. Infests ducks and geese, especially at the base of large wing feathers. *Squalid duck louse, Lipeurus squalidus* Nitzsch.

10. A short broad species $^1/_{25}$ inch long, with abdomen squarish behind; whitish with a brown margin. Infests pigeons. *Broad pigeon louse*, page 820.

11. An exceedingly slender louse about $\frac{1}{12}$ inch long, with dark abdomen and reddish-brown head and thorax, very abundant on old pigeons and partially feathered squabs. *Slender pigeon louse*, page 820.

C. *Minute, almost invisible, eight-legged, rounded mites that burrow into the skin beneath scales of legs or at base of feathers and feed and reproduce in the tunnels:*

1. Chickens, turkeys, pheasants, and other birds walk painfully or refuse to walk. Legs are encrusted with elevated scales from under which a fine white powder and serum exude from the irritated and inflamed skin, and the legs become much swollen. Numerous minute, circular, very short-legged mites less than $\frac{1}{50}$ inch long burrow under the scales. *Scaly leg mite*, page 821.

2. A similar but still smaller mite, burrows into the skin at the base of the feathers of the rump, back, abdomen, head, and neck of chickens and pigeons, causing the feathers to fall or to be pulled out by the bird. If the stumps of such feathers are examined, an abundance of dry scales, crusts, and mites will be found. *Depluming mite*, page 822.

General References.—N. Y. (Cornell) Agr. Exp. Sta. Bull. 359, 1915; *Ohio Agr. Exp. Sta. Bull.* 320, 1917; *Conn. (Storrs) Agr. Exp. Sta. Bull.* 86, 1916; *U. S. Dept. Agr. Farmers' Bulls.* 801, 1917; and 1110, 1920.

Poultry Mite or Chicken Mite[1]

Importance and Type of Injury.—These mites (Fig. 544), live in cracks about the roosts, floors, walls, or ceiling of the houses in the daytime and crawl upon the fowls at night or when they are on the nests. Only a very few mites are found on fowls during the daylight hours. Their only normal food is the blood of fowls, which they draw through their sharp piercing mouth parts at night. Since they rarely stay on poultry during the daytime, a flock may be badly run down by them without the owner's being aware of the cause of the trouble. Small areas about the roosts or elsewhere in the house show patches of brown mites or fine black- and white-speckling as though dusted with pepper and salt—the excrement of the mites. When they become extremely abundant, the litter and manure may appear to be literally crawling with tiny gray-and-brown specks. The mites are especially abundant where the roost timbers rest on their supports. The fowls become droopy, pale about the head, and listless, and stop laying. Sitting hens and chicks often die.

Animals Attacked.—Chickens are preferred, and other poultry is not likely to be badly attacked if chickens can be reached. The mites often greatly irritate persons or animals about infested houses.

Distribution.—Practically cosmopolitan; more troublesome in the warmer regions.

Life History, Appearance, and Habits.—The mites become inactive and greatly reduced in numbers during cold weather, except in heated houses, although feeding and breeding to some extent may take place during warm spells, even in winter. With the advent of spring, activities are greatly accelerated. The females deposit their pearly-white oval

[1] *Dermanyssus gallinæ* (DeGeer), Order Acarina, Family Gamasidæ.

eggs in dark protected places, such as cracks between timbers or in dry manure under the roosts. Two or three dozen eggs are laid over a period of several weeks. The eggs hatch in 3 or 4 days on the average. Several days more elapse, and the young six-legged nymph sheds its skin once and becomes eight-legged before it seeks a fowl and fills up on blood (Fig. 544). After engorging, it hides away in some dark place for a day or two or until it sheds its skin again. It then finds a host, engorges on blood a second time and again hides away for a day or two before it makes the third and final molt and becomes an adult. It requires only 1 week to 10 days to pass through the stages from egg to adult. The adults are $^1\!/_{40}$ to $^1\!/_{30}$ inch long, grayish in color but when filled with

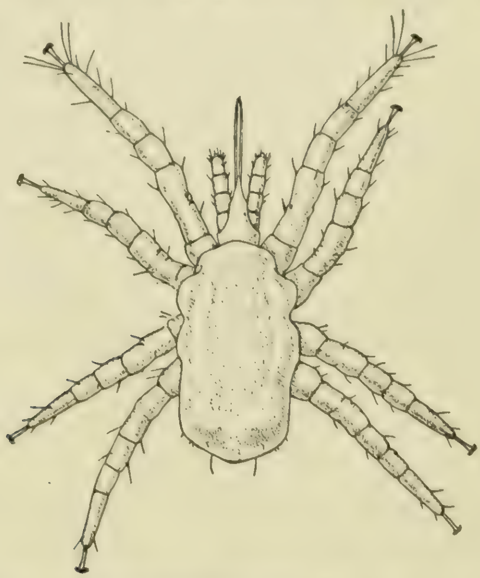


FIG. 544.—The poultry mite, *Dermanyssus gallinæ* (De Geer); nymph before engorging on blood. Greatly magnified. (*From U. S. D. A. Farmers' Bull.* 801.)

blood appearing bright red to nearly black. It is believed that the same adult does not feed every night, but after filling up on blood, leaves the fowl and during the next few days lays three to seven eggs, then feeds and repeats the process until all the eggs have been laid.

Control Measures.—For the control of these mites attention must be given to the house rather than to the birds themselves. A very thorough clean-up of the poultry house is essential, since the mites abound in filth and infest any crack about the house big enough for them to crawl into. This should be followed with a thorough spraying of crude petroleum, carbolineum, or anthracene oil, mixed with half its volume of kerosene, using a pump that gives a strong penetrating spray, and treating the floor, the walls, and, in badly infested houses, the roof and outside of the walls. If the above oils are not available, kerosene alone may be used, but several treatments a week or 10 days apart will be necessary. Arsenical or coal-tar stock dips are also recommended. The spray should be applied in the morning so the oil will have dried before the fowls go to

roost. After the clean-up, the cracks of the roosts and the supports on which they rest should be brushed over once a month with crude petroleum or anthracene oil to catch any mites that escaped the first treatment. Mites may live 4 or 5 months in a house after all poultry has been removed, especially if surroundings are moderately moist. These pests may also stay on the bodies of fowls in small numbers for at most about 3 days. When moving fowls to a new building or introducing new birds to a flock, they should be isolated for 3 days and nights in pens so that the mites will all crawl away from them. Poultry houses should be so constructed as to receive plenty of light and air, to be dry and to be easily cleaned. It is important that roosts, nest boxes, and all other boards and fixtures be arranged so they can easily be removed for cleaning and spraying outside the house.

References.—*U. S. Dept. Agr. Dept. Bulls.* 553, 1917; and 1228, 1924.

Feather Mite or Tropical Fowl Mite[1]

Importance and Type of Injury.—Small reddish or brown, eight-legged mites swarm over the skin, congregating about the vent, where they may cause bloody scabs to form. The feathers in this region become dirty from the eggs and excreta of the mites. Heavy infestations kill the fowls from loss of blood and irritation. This mite has been suspected of transmitting the dangerous tropical disease, fowl spirochætosis.

Animals Attacked.—Chickens and other domestic fowls; English sparrow, starling, and other wild birds.

Distribution.—This pest has been known in this country only since 1916, but it is already widely distributed throughout the northern, eastern, and central states. The infestations have been local and many of them have been cleaned up.

Life History, Appearance, and Habits.—These mites are very similar in a general way to the poultry mite. They are slightly smaller, more hairy, and with smaller legs; they move more rapidly, and the tip of the abdomen of the female is slightly notched. In habits, however, they are very different, since they live day and night on the body of the fowl instead of harboring in cracks about the house, and also lay their eggs on the fluff feathers. The eggs adhere to the barbules of the feathers and are also found in the nests.

Control Measures.—Fowls should be dipped during warm weather. Wood and Cleveland recommend a dip made by dissolving 1 ounce of soap in a gallon of water and stirring into it 2 ounces of fine flowers of sulfur. The fowls must be entirely submerged in the dip and the feathers ruffled to permit the liquid to reach the skin. If an infestation is discovered in cold weather the fowls should be dusted very liberally and thoroughly with very fine flowers of sulfur, to hold the mites in check until the weather is warm enough to permit dipping. Since the mite is known to live in the nests and on the bodies of English sparrows, these birds should be fought and their nests burned to prevent spread. New birds or show animals should be isolated before introducing them to a clean flock, and carefully examined to make sure they are not infested. If any mites are found, treat as suggested above. The nests used by infested fowls, and in cases of bad infestations the entire house, should be treated as described for the poultry mite.

Reference.—*Poultry Science*, Vol. 2; pp. 129–135, 1923; *U. S. Dept. Agr. Dept. Circ.* 79, 1920.

[1] *Liponyssus* sp., Order Acarina, Family Liponyssidæ.

Fowl Tick or Bluebug[1]

Importance and Type of Injury.—The injury and symptoms of attack by fowl ticks are much as in the case of poultry mites; weakness of the legs, droopy wings, pale comb and wattles, cessation of egg laying and death from loss of blood. Small, rounded, reddish or dark-colored objects attach in clusters to the skin on neck, breast, thighs, or under wings, sucking blood and causing great irritation. Large, reddish or blue ticks up to ½ inch long are found in daytime under bark of trees where the fowls roost or under loose boards about the henhouse or where roost poles meet the walls; and black spots of excrement stain the woodwork near such cracks. These large ticks suck their fill of blood in about ½ hour, and when they are abundant profitable poultry husbandry is out of the question unless control measures are applied. In addition to bleeding fowls, the fowl tick is the proved carrier of a highly fatal poultry disease known as fowl spirochætosis in many parts of the world. There is danger that this disease may be introduced into North America.

Animals Attacked.—Chickens are the preferred host, but all other domestic fowls and some wild fowls are attacked, and rarely domestic mammals and man.

Distribution.—In the southwestern states from Texas westward to California, and in Florida. Apparently limited to warm, semiarid regions.

Life History, Appearance, and Habits.—In cooler regions the ticks appear to winter chiefly as adults and half grown nymphs. Throughout most of its range breeding may continue slowly even in winter. They thrive best, however, in hot, dry weather. The adults are flattened, leathery, eight-legged, with thin edges to the body, egg-shaped in outline and red to blue-black in color. They range in size from about ¼ to ½ inch long. The brownish eggs are laid in cracks about the house. They hatch in from 10 days to 3 months, and the grayish six-legged nymphs seek a fowl, particularly at night, and attach in bunches to the skin and suck blood from 3 to 10 days in one spot. They then release their hold and hide away in a protected place for about a week, molting and acquiring the fourth pair of legs. From this time on they suck blood only at night, hiding in cracks during daylight and alternately engorging and molting at intervals of a week or two until they become adult. The females deposit several lots of eggs, a total of 500 to 900. There is normally one generation a year, but if deprived of a host the adults may survive for 2 or 3 years without food or water.

Control Measures.—Control is much the same as for the poultry mite, but must be given with extreme thoroughness because these flattened ticks can hide deeply in cracks and are most hardy and resistant creatures.

[1] *Argas miniatus* Koch (*persicus* Oken), Order Acarina, Family Argasidae.

Roosts should be suspended by wires from the ceiling or supported entirely from the floor so that they do not touch the walls. Nests should be so constructed that they can be easily removed and treated. Poultry must not be allowed to roost in trees, barns, and other shelters which cannot be treated effectively. Any new fowls brought into the flock should first be isolated for 10 days to allow the seed ticks to drop off, and the temporary quarters then treated or burned.

Reference.—U. S. Dept. Agr. Farmers' Bull. 1070, 1919.

Sticktight or Southern Chicken Flea[1]

Importance and Type of Injury.—In the south and southwest poultry sometimes show clusters of dark-brown objects about the face, eyes, ear lobes, comb, and wattles made by hundreds of small flattened fleas that have their heads embedded in the skin so that they cannot be brushed off. Young fowls are often killed, and egg laying and growth are greatly checked by the loss of blood and the great irritation caused by the bites.

Animals Attacked.—Chickens, turkeys, and other poultry, and, according to Herms, also cats, dogs, horses, and man.

Distribution.—Southern and Southwestern United States from South Carolina to California.

Life History, Appearance, and Habits.—Adult males and females are found, often *in copula*, on the heads of fowls. The females at least remain attached by their mouth parts in the same spot sometimes as long as 2 or 3 weeks. During this time the eggs are laid, being thrown with considerable force from the vagina of the female. The eggs hatch on the ground in from 2 days to 2 weeks, and the slender white larvæ feed on the excreta of the adult fleas and possibly other filth in the cracks and litter about the floor of henhouses or on the ground in dry protected places. After a growing period of 2 weeks to 1 month, they spin silken cocoons covered with dust and dirt, in which the pupal transformation occurs. The adults do not attach to the host for several days or 1 week and then a second period of about 1 week elapses before the females begin laying eggs. Only a few eggs, one to five, are laid at a time. The life cycle may be completed in from 1 to 2 months. The pest thrives best in dry, cool weather, and the adults may live for several months under such conditions.

Control Measures.—Thoroughly clean the house and yards, burning the dirt and litter on the spot, or soaking it with kerosene or creosote oil; or cover the ground with a uniform thin layer of lime; or treat with kerosene or boiling water. Keep dogs, cats, and rats away from poultry houses, as they may spread this flea. Exclude fowls from beneath buildings.

Reference.—Okla. Agr. Exp. Sta. Bull. 123, 1919; *Jour. Agr. Research*, Vol. 24, pp. 1007–1009, 1923; *U. S. Dept. Agr. Farmers' Bull.* 897, 1917. Herms "Medical and Veterinary Entomology." 2d Ed., 1926; *Jour. Agr. Research*, Vol. 24, p. 1, Apr. 7, 1923.

Poultry Lice[2]

Importance and Type of Injury.—Contrary to the belief of most poultry men, the lice that live on fowls do not suck blood. They feed by

[1] *Echidnophaga gallinaceæ* (Westwood), Order Siphonaptera, Family Sarcopsyllidæ.
[2] Order Mallophaga.

nibbling or chewing the dry skin scales, feathers, or scabs on the skin. The irritation from the mouth parts, together with that of the sharp claws on their feet in running about over the skin, results in a nervous condition of the infested birds that prevents sleep, causes loss of appetite and diarrhoea, and renders the weakened fowls easy prey for various poultry diseases. Young chickens and turkeys that are brooded by lousy hens are often killed in great numbers by the swarming of lice from the hen to them almost as soon as they hatch from the eggs. The most serious effect upon older fowls is a reduction in the number of eggs laid. Infested fowls are in a mopy, drowsy condition with droopy wings and ruffled feathers, refuse to eat and gradually become emaciated. If the feathers of such a fowl are parted, the lice will often be found running about on the skin in great numbers, particularly below the vent, on the head, or under the wings.

Animals Attacked.—Every kind of domestic fowl (and probably every kind of wild bird as well) has from one to several kinds of lice. In general, each species of bird has lice peculiar to it. The exceptions to this will be noted in discussing the different lice. At least a dozen kinds attack chickens and three to five different kinds are found on ducks, pigeons, and turkeys.

Distribution.—Wherever fowls are kept.

Life History, Appearance, and Habits.—Poultry lice generally breed faster and become more abundant in summer than in cold weather, but all stages can usually be found on the host in winter. All of these chewing lice are permanent parasites spending all life stages, generation after generation, on the same bird, and never normally leaving its body, except as they pass from one fowl to another, particularly from old to younger birds. The eggs are cemented fast to some part of the feathers. They are oval in shape, generally white in color and often beautifully ornamented with spines and hairs (Fig. 73, *J*). While laid singly they may be abundant enough to form dense clusters on the fluffy feathers of badly infested chickens. In a few days or weeks the young nymph hatches from the egg in a form much like the parent lice only much smaller and paler in color. It at once begins running about and feeding, and in the course of the next few weeks passes through several molts, gradually assuming the size, form, and coloration of the adult.

Poultry lice are entirely wingless, six-legged insects with a much flattened body and broad head rounded in front. The mouth parts are near the middle of the under side of the head, the most prominent parts being two sharp-pointed teeth or mandibles. The legs are good-sized, and in all of the species that live on birds they have two claws at the end of the tarsus. Their relatives that live on hair-bearing animals, such as the little red louse of cattle or the chewing lice of horses and sheep, have only one tarsal claw, fitted for grasping about the hairs.

The head louse[1] (Fig. 545) is especially noticeable and injurious on young chicks and turkeys. The dark gray large-headed adults, about 1/10 inch long, and the paler young ones are found standing head down along the base of the feathers on top of the head with their mouth parts against the skin. They constantly nibble at the skin scales but apparently never eat through the skin nor into the flesh. Although they move about only a little, they pass very early from brooding hens to little chicks, which are often killed by them. The eggs are cemented to the barbs of

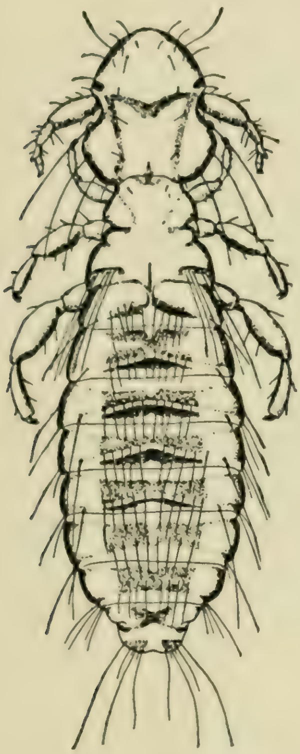


FIG. 545.—Head louse of poultry, *Lipeurus heterographus* Nitzsch; male, about twenty-five times natural size. (*From U. S. D. A. Farmers' Bull.* 801.)

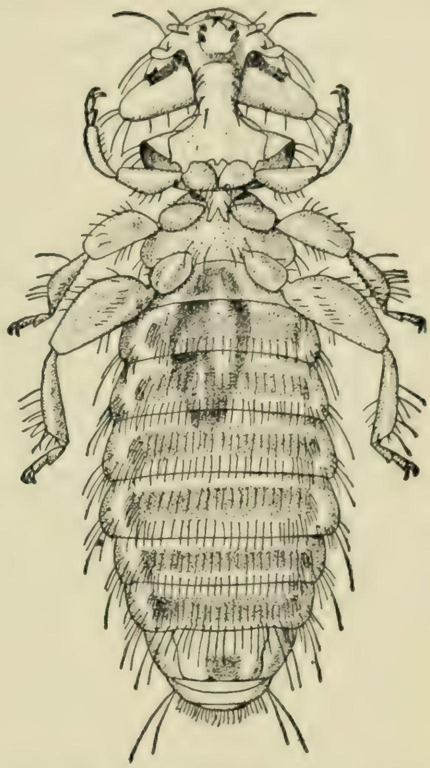


FIG. 546.—Large body louse of poultry, *Menopon biseriatum* Piaget; female, underside, about twenty-five times natural size. (*From U. S. D. A. Farmers' Bull.* 801.)

the down or small feathers of the head or neck. They hatch in about 5 days and the young are full-grown in about 10 days more.

The large body louse[2] (Fig. 546), lives most of the time on the skin of either chickens or turkeys, being especially abundant about the vent and under the wings and common on both young and old fowls. When the feathers are parted, all sizes of the lice run rapidly to cover. The smaller ones are pale yellowish white but the larger ones, which reach a length of nearly 1/8 inch, appear brownish. The body is covered with fine long hairs. Bishopp and Wood consider this the most injurious louse of grown chickens, because it is constantly on the skin. The eggs are fastened to the basal barbs from the shaft of the feathers, especially below the vent.

[1] *Lipeurus heterographus* Nitzsch, Order Mallophaga, Family Liotheidæ.

[2] *Menopon biseriatum* Piaget, Order Mallophaga, Family Liotheidæ.

They are said not to hatch on feathers dislodged from the host. On the body they hatch in about a week, and 10 or 12 days of growth brings the nymphs to the adult stage. They increase very rapidly: Lawson and Manter record having counted over 35,000 lice on one chicken, which they think was not half of those actually present.

The shaft louse, small body louse, or common body louse[1] is similar to the large body louse in appearance, but it is distinctly smaller (1/16 inch long), paler colored, and less hairy. It has commonly been considered the most injurious louse of chickens but Bishopp and Wood contend that it lives mostly on the feathers, lying along the shaft and running down the feathers to the skin when the feathers are parted. It is very common about the vent, also on the back and breast. It does not infest young chicks, presumably because of the lack of well-developed feathers. The eggs are fastened to the base of feathers and hatch in 2 or 3 weeks. These lice are very hardy, having been kept alive for 9 months. This species occurs on ducks, turkeys, and guineas, at least when they are housed with chickens, and is sometimes troublesome to horses stabled near badly infested poultry.

The other lice on chickens are less abundant and less important, and live chiefly among the feathers, where their nibbling and crawling does not cause great annoyance. The lice that attack turkeys, geese, and ducks are said to be less abundant and generally not sufficiently injurious to require special treatment. Pigeons, however, often become grossly overrun with the broad pigeon louse[2] or the slender pigeon louse,[3] which live among the feathers of both old and young birds and doubtless interfere with the profitable raising of these fowls.

Control Measures.—It should be evident from the different life habits of lice and mites that to control *lice*, with the measures discovered up to the present time, as described below, it is necessary to apply some substance directly to the *body* of the fowl; whereas, with poultry *mites*, treatment of the *house* is essential. In both cases cleanliness, an abundance of fresh air and light, a good supply of drinking water, and the provision of good clean dust baths are important factors in keeping these external parasites and the injurious effects from them in subjection.

In the past 10 years, commercial sodium fluoride[4] has been found to be so effective in the control of poultry lice that it is now generally accepted as the most important remedy. Fowls should be examined every few months, and, if found infested, every fowl on the premises should be treated, since a single one that escapes the clean-up may soon reinfest the entire flock. The sodium fluoride may be used either as a dust or as a

[1] *Menopon pallidum* Nitzsch, Order Mallophaga, Family Liotheidæ.

[2] *Goniocotes compar* Nitzsch, Order Mallophaga, Family Philopteridæ.

[3] *Lipeurus baculus* Nitzsch, Order Mallophaga, Family Philopteridæ.

[4] Care must be taken not to confuse this with sodium chloride, which is ordinary table salt, since the two names sound so much alike.

dip, but in cold weather dipping is not advisable. The dip should be prepared in a wooden tub or large earthenware jar, dissolving 1 ounce of sodium fluoride and 1 ounce of laundry soap to each gallon of water. Hold the fowl by both wings with one hand, lower it in the water and ruffle the feathers for about ½ minute until they are soaked to the skin; then duck the head under twice, and the fowl is ready to release. In dusting with sodium fluoride it is best to lay the fowl over a shallow pan or paper on a table. A "pinch" of the powder is sifted among the feathers next to the skin on the head, another on the neck, two on the back, one on the breast, one below the vent, one on the tail, one on each thigh and one on the under side of each wing. The cost for materials in such treatment is trivial, not over a half cent per fowl. Instead of using the pinch method, the powder may be sifted among the feathers, next to the skin, on all parts of the body from a talcum box or other can with small holes in the top, giving especial attention to the region around the vent. An ounce of the material is sufficient to treat from 50 to 100 hens. One treatment carefully given should completely eradicate the lice. In dusting, the lice are not all killed for several days, but when the fowls are dipped, the death of the lice occurs very promptly.

Mercurial ointment (50 per cent metallic mercury) thoroughly mixed with 1 to 2 parts of vaseline makes an effective ointment for head lice. A lump not larger than a pea should be thoroughly rubbed over the feathers on top of the head. Care should be used not to apply too much. Carbolated vaseline or even lard is recommended to be used in the same way.

Scaly-leg Mite[1]

Importance and Type of Injury.—This species and the following one are close relatives of the mites and ticks discussed earlier in this chapter, but their habits are quite different. They are more like mange or itch mites, since they remain on the body all of the time and make tunnels in the skin, in which the eggs are laid. The scaly-leg mite attacks especially the feet and lower part of the legs but is also found about the comb. The scales of the legs (Fig. 547), become elevated, and a fine white dust sifts from beneath them. Lymph and blood exude and red blotches form on the legs. The birds become crippled or even unable to walk at all. Great irritation must result from the burrowing of the mites.

Animals Attacked.—Poultry; and rabbits, guinea pigs, and other animals housed near infested birds.

Life History, Appearance, and Habits.—This trouble is caused by a tiny, eight-legged mite, measuring from 1/100 to 1/50 inch across, pale gray in color and nearly circular in outline. They are not seen by the naked eye. If the fowl's legs are soaked in warm, soapy water, the scales may

[1] *Cnemidocoptes mutans* Robin and Lanquentin, Order Acarina, Family Sarcoptidæ.

be lifted and the mites found by use of a microscope among the powder and lymph from beneath the scale. They have very short legs and the skin is traversed with fine lines as is the palm of one's hand. It is believed that the eggs are laid in the tunnels made by females beneath the skin scales. Like other mites, the young are at first six-legged and the development from that point on is a simple metamorphosis.

Control Measures.—Poultrymen should be on the lookout for this trouble, especially on newly purchased birds, and should treat fowls as

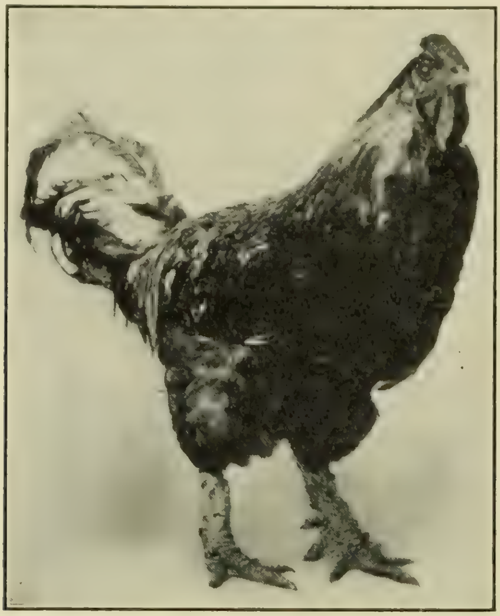


FIG. 547.—Rooster severely attacked by scaly-leg mite, *Cnemidocoptes mutans* Robin and Lanquentin. (*From U. S. D. A. Farmers' Bull.* 1337.)

soon as the symptoms show up to prevent spread to others. The legs may be brushed with, or dipped in, crude petroleum or a mixture of raw linseed oil, 2 parts, and kerosene 1 part. If the swollen scales are not largely shed within a month, the treatment should be repeated; but one treatment is usually sufficient.

THE DEPLUMING MITE[1]

This mite is similar to the scaly-leg mite but is still smaller, and it burrows into the skin at the base of the feathers on the rump, back, head, abdomen, and legs. The mites may be found on the fallen feathers or among the dry powdery material in the skin. The irritation from the mites causes the fowls to pull out their feathers.

Control Measures.—Sulfur ointment carefully applied to the affected parts, or a dip made by mixing 2 ounces of flowers of sulfur and ½ ounce laundry soap to the gallon of water. Repeated applications will be necessary. The affected birds should be isolated.

Reference.—U. S. Dept. Agr. Farmers' Bull. 957, 1918.

[1] *Cnemidocoptes lævis* (*gallinæ*) Railliet, Order Acarina, Family Sarcoptidæ.

Bedbug[1]

The common bedbug (see Fig. 553) and several of its close relatives[2] are frequently pests in poultry houses. They hide, breed, and lay their eggs in nests, behind nest boxes, under loose boards, and in other cracks about the walls, roosts, and roof of the building. At night the nymphs and adults find their way upon the sleeping hens and suck their blood. They are almost never found on the fowls in daytime. Sitting hens suffer especially from these pests and may be driven to leave the nests. The small black spots of excreta from the bedbugs may often be seen on the eggs and about cracks.

Control Measures.—Because of the likelihood of carrying these bugs into the house, quite as much as on account of their injury to the fowls, vigorous control measures should be applied. Effective measures are given in the chapter on insects affecting man (p. 836). In most cases, chicken houses can be rid of these pests by spraying all cracks thoroughly with creosote oil or crude petroleum.

[1] *Cimex lectularius* Linné, Order Hemiptera, Family Cimicidæ.

[2] The Mexican chicken bug, *Hæmatosiphon inodorus* Duges, the European pigeon bug, *Cimex columbarius* and the barn-swallow bug, *Œciacus vicarius* Horvath.

CHAPTER XXIII

INSECTS THAT ATTACK AND ANNOY MAN AND AFFECT HIS HEALTH

The various ills man suffers from insects reach their climax in their attacks upon his person. "Bugs" are no respectors of persons. While for the most part decent, sanitary living and reasonable precautions about associating with less sanitary persons and surroundings will prevent these insects from attacking a given individual, nevertheless some of these unwelcome visitors are likely to come into any household at any time. In such a case, to be forewarned is to be forearmed. The housekeeper who knows when to ignore a newfound insect in her house as a creature of no real significance and when to fight one that may start an infestation which could cause trouble for months, has the battle half won. Brues[1] says:

> The importance of insects as detrimental to public health is well known to professional zoologists, medical men, and laymen alike, but is usually emphasized only under the stress of particular circumstances, such as the safety of soldiers in the recent war or of unusual outbreaks of diseases for which insects are directly responsible. Insect-borne diseases present a *constant* menace to the world, and aside from the actual toll of lives which they exact, they impair its efficiency by enfeebling the health of its human population.

W. D. Hunter, in his address as President of the American Association of Economic Entomologists,[2] draws the conclusion that the losses caused by diseases transmitted by insects is approximately one-half as great as the losses caused to all farm products. He concludes: "Surely this is a sufficient argument for greater attention to medical entomology."

FIELD KEY FOR THE IDENTIFICATION OF INSECTS THAT ATTACK AND ANNOY MAN AND AFFECT HIS HEALTH

A. *Free-flying insects that alight on face, arms, and other exposed parts of the body to bite and suck blood:*

1. Slender-bodied, long-legged insects up to ½ inch long with delicate wings fringed with scales and long slender mouth parts and bushy antennæ make a high-pitched humming noise as they alight to suck blood. Especially abundant at dusk or at night and about swamps and woodlands. *Mosquitoes*, page 827.

2. Small, chunky, humpbacked gnats not over ⅕ inch long, with broad clear wings and short heavy mouth parts and antennæ, alight on the body, crawl into eyes,

[1] Brues, C. T., "Insects and Human Welfare," Harvard University Press, 1920.

[2] Hunter, W. D., *Jour. of Econ. Entomol.* Vol. 6, pp. 27–39, February, 1913.

ears, hair, or under the clothing and suck blood. They make comparatively little noise and the bite at first is not very painful. Especially troublesome during the daytime. *Black flies*, page 832.

3. Very small midges, not over $\frac{1}{10}$ inch long, with hairy but not scaly, sometimes mottled, wings, bite in the daytime. They fly quietly and are seldom seen or heard until the hot, very painful bite is inflicted. *No-see-ums*, page 834.

4. Large, heavy-bodied, brown, black, and orange, often green-eyed flies, about $\frac{1}{2}$ inch long, with wings clear or banded, fly wildly about the head with much noise, and cause a very painful, bloody bite on arms, head, or neck. Encountered chiefly in woods or marshes on warm sunny days. *Deer flies* or *horseflies*, page 835.

5. A fly about the size and general appearance of the house fly often comes indoors in lowering weather and bites especially about the ankles. It differs from the house fly in having a stiff, pointed beak that projects forward from lower side of the head, a broader, black-spotted abdomen, and grayer appearance, and hairs on upper side of arista only. *Stable fly*, pages 770 and 835.

B. Insects that crawl upon the body to bite and suck blood, not spending their entire life on the human host:

1. Mahogany-brown, broad, very flat or thin, oval, wingless bugs, of all sizes up to $\frac{1}{5}$ inch long, live in beds and cracks about the room and crawl over the body and bite at night. Bugs have a distinct disagreeable odor. *Bedbug*, page 836.

2. Large, somewhat flattened, oval bugs, brownish or black, sometimes marked with pink or red; between $\frac{1}{2}$ and 1 inch long, tapering to a slender head in front, with well-developed wings crossing over on the back. They bite when picked up, and in some localities regularly visit the bodies of sleeping persons to suck their blood. *Mexican bedbug*, *kissing bug*, and other *assassin bugs*, page 837.

3. Small, brown, wingless insects, about $\frac{1}{16}$ inch long, very flat from side to side and with long hind legs, slip into the clothing or jump vigorously when disturbed. They bite especially about the legs and waist. Troublesome chiefly in basements or houses where dogs or cats are allowed. *Cat flea*, *dog flea*, *human flea* and others, page 839.

4. In southern states or tropical countries, painful, inflamed sores develop between the toes or under the toenails, each containing an ulcerated body that may become as big as a small pea. This is due to a flea that buries its body in the skin. *Chigoe flea*, page 841.

5. Tough-skinned, eight-legged, reddish brown to bluish-gray, seed-like bodies up to $\frac{1}{2}$ inch long, often with silvery-white markings on the hard plate near the head, sink their mouth parts deeply and firmly in the skin and suck blood. No particular pain is felt at the time, but motor paralysis, infected sores or spotted fever may follow the attack. *Spotted-fever tick*, *castor-bean tick*, *dog tick*, *and others*, page 842.

6. An eruption on the skin like hives or chicken pox, accompanied by severe itching, and sometimes nausea, headaches, chills, or fever, results from handling straw or flour, dried fruits, meat, and other groceries, or follows a visit to grassy, brambly spots out-of-doors. Caused by nearly microscopic mites that crawl upon the skin and bite. *Chiggers*, *harvest mites*, *louse-like mites* or *flour and meal mites*, pages 845 to 848.

C. Insects that live upon the body all of their lives, generation after generation:

1. Extreme itching of tender places on the skin, such as between the fingers, behind the knee, and inside the elbow, without visible cause. Careful examination may reveal delicate, tortuous, gray thread lines just beneath the skin. Hard pimples as big as pinheads, containing a yellow matter, form on the skin. Scraping the affected spots to the "quick" and examining the scrapings under a lens reveals very small, whitish, eight-legged, nearly round mites. *Itch mite*, page 848.

2. Painful burning and itching bites, which become whitish scars ringed with brown pigmented skin, occur anywhere on parts of body covered by clothing. No "cause" found on the skin but examination of clothing about the neckband, armpits, waist, or crotch of trousers, reveals elongate, oval, flattened, wingless, gray lice, up to $\frac{1}{8}$ inch long, with six legs, each bearing a single curved claw at the end. Whitish keg-shaped eggs are laid in the seams of the clothing. *Body louse, grayback*, or *cootie*, page 849.

3. Hair of the head, especially back of the ears and at the nape of the neck infested with crawling, grayish, six-legged lice, similar to the above; the whitish eggs fastened to the hairs. *Human head louse*, page 849.

4. Painful burning and itching bites with small inflamed spots among the hairs between the legs. Small, broad, grayish, six-legged lice up to $\frac{1}{16}$ inch long, that look something like miniature crabs and tend to remain fixed in one spot. *Pubic louse* or *crab louse* page 853.

D. *Short, whitish, legless, segmented maggots or "worms"*[1] *live under the skin in sores, or in the natural body cavities, or in the alimentary canal, and are not infrequently passed in the excreta:*

1. The maggots taper gradually from a blunt posterior end, which bears two rounded plates or short tubes for breathing, to a pointed head end which has short mouth hooks. Various *flesh flies*, *house flies*, *fruit flies*, and *root-maggot flies*, page 854.

2. The maggots are thickest near midlength and narrow strongly toward either end; the skin is very tough, and usually beset with many, minute, short, sharp spines. *Human botflies*, page 854.

3. The maggots are flattened, narrowing toward either end, each segment with prominent, fleshy, pointed processes, some of which have minute side spines. *Latrine fly* and *little house fly*, page 855.

4. The maggots are nearly cylindrical, with head end rounded off and the opposite end prolonged into a long slender "tail" that is extensible like a telescope. *Rat-tailed maggots*, page 855.

E. *Insects that frequent both filthy materials and human habitations and carry diseases to man without inflicting pain on the body:*

1. Two-winged flies, about $\frac{1}{4}$ to $\frac{1}{3}$ inch long, of a general grayish color, with four equal black stripes on the back between the wings; the arista or antennal bristle feathered, *i.e.* hairs coming off on two sides of it; the mouth parts soft, spongy, and retractile; the vein that ends nearest the tip of the wing bent forward so as nearly to meet the vein in front of it at the wing margin; and no large, bristly hairs on front segments of the abdomen. *House fly*, page 855.

2. Flattened, oval, running, brown or black, nocturnal insects from $\frac{1}{2}$ to $1\frac{1}{2}$ inches long, with six long, very spiny legs, antennæ longer than the body, and usually four, finely veined wings that are seldom used; occur in kitchens, bakeshops, restaurants, public buildings, ships and other moist, warm places. *Cockroaches*, page 742.

F. *Insects and other Arthropods that accidentally or occasionally hurt man, in defense of themselves or their nests, by stinging, biting, nettling, or blistering the skin:*

1. Four-winged, swift-flying, smooth or very hairy insects, usually conspicuously marked with yellow, insert the ovipositor or "stinger" from the posterior end of the body, and inflict a painful sting. *Bees*, *wasps* and *hornets*, pages 17 and 214.

2. Wingless, crawling, six-legged, slender-waisted "ants," the hairy kinds often brilliantly colored, sting as in *F*, 1. *Stinging ants* and *velvet ants*, page 17 and 218.

[1] Not to be confused with the parasitic *round worms* and *flat worms*, which are usually much longer. These, if cylindrical, are not segmented, and if segmented are much flattened. Insect larvæ never show more than thirteen segments.

3. Bugs of various sizes and shapes up to 2 inches long, but all with a slender tubular beak projecting from the lower side of the head, six legs, and the front pair of wings thicker at base and thinner and overlapping at the tip; bite painfully when handled or when they fly against the face, especially at night. *Assassin bugs, water scorpions, electric light bugs*, and many other *Hemiptera*, pages 16 and 837.

4. Wingless, dark-colored, eight-legged creatures with the body in two regions, the part bearing the long legs separated from the abdomen by a slender pedicel or stalk, puncture the skin and introduce a venom with the mouth parts. *Tarantulas* and other *spiders*, page 165.

5. Elongate creatures, commonly 2 or 3 inches long, with a pair of "pincher legs" in front, eight long walking legs at the middle and a very long abdomen in two parts, the posterior slender part with a short swollen sting on the end; cause great pain by thrusting this sting into the flesh. *Scorpions*, page 167.

6. Elongate, worm-like "hundred-legs," from 1 to 10 inches long, with distinct head and antennæ, somewhat flattened body, and 15 or more pairs of legs, "bite" with a pair of poison claws just back of the head. *Centipedes*, page 163.

7. Caterpillars ("worms") of a variety of sizes and colors, but always with three pairs of jointed legs and five pairs of fleshy prolegs, and generally more or less spiny or woolly, nettle the skin when they brush against it, causing pain, itching, and inflamed spots. *Various caterpillars* or *moth larvæ*, page 17.

8. Elongate, rather soft-shelled, six-legged beetles, commonly ½ to ¾ inch long, blister or corrode the skin if crushed upon it. *Spanish fly*, and other *blister beetles*, pages 18 and 474.

General References.—Herms, "Medical and Veterinary Entomology," 2d Ed. 1923; Riley and Johannsen, "Handbook of Medical Entomology," 1915; Herrick "Insects Injurious to the Household and Annoying to Man," 1921.

Mosquitoes

Importance and Type of Injury.—Besides the well-known painful bites inflicted by the females of all kinds of mosquitoes, these insects are the proved carriers of four distinct human diseases. There is no other known method of acquiring malaria, yellow fever, dengue and certain forms of filariasis except by the bites of mosquitoes which have previously bitten persons that had these diseases.

Considering the entire world, malaria ("ague" or "chills and fever") has been said to be the most important disease. It causes a large percentage of the deaths among mankind. In the United States (which is only mildly malarious) there are 10,000 or 12,000 deaths a year, in addition to which several millions suffer illness, loss of time and, often prolonged inefficiency from this disease. The proper agricultural development of certain sections of our country has been greatly retarded, and in the tropics entire countries have been practically barred from civilization, by this disease. As pointed out by Ross, these are unfortunately "more especially the fertile, well-watered and luxuriant tracts; precisely those which are of the greatest value to man."

The several kinds of malaria are caused by microscopical animals[1] that live in the blood, destroying the red corpuscles and causing anemia,

[1] Three species of *Plasmodium*, Phylum Protozoa, Class Sporozoa.

accompanied by the characteristic alternating chills, fever, and sweating. Once introduced to a human body by a mosquito, the parasite may increase rapidly until as many as 3,000,000,000 are present in the blood of one patient; but it cannot get from that person to another without the help of certain kinds of mosquitoes[1] (Figs. 549 and 550), in the bodies of which a necessary part of its life cycle is completed. Every step of the life cycle of this little animal has been followed in both the human and insect hosts and we know that both man and mosquito are necessary to its continued existence.

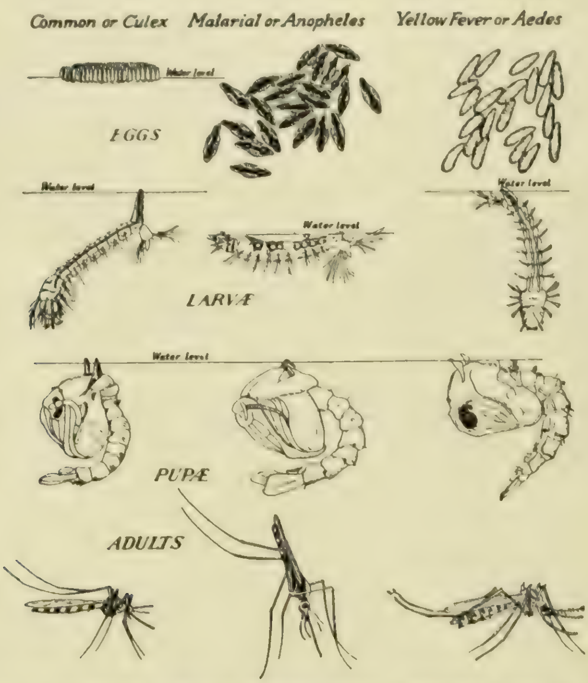


FIG. 548.—Three important kinds of mosquitoes, showing egg, larval, pupal and adult stages of each: in the left-hand column the life stages of a common house mosquito, in the center column of a malarial mosquito, and in the right-hand column of the yellow-fever mosquito. Two or three times natural size. (*From "Everyday Problems in Science," by Pieper and Beauchamp, Copyrighted, 1925, by Scott, Foresman and Company*).

Until the end of the nineteenth century, yellow fever was one of the most dreaded diseases in the world. Its cause was not known, and terrible epidemics swept tropical countries and our seaport towns such as New Orleans, Philadelphia, and Havana. This disease was the most potent factor in the failure of the French to build the Panama Canal, in the latter part of the last century. In 1900, American army surgeons working in Cuba discovered that the disease is spread exclusively by a particular kind of mosquito,[2] since known as the yellow-fever mosquito. Since this discovery the disease has been rapidly stamped out of country after country until it has now been nearly eradicated from the earth.

[1] Fifty or more species of the genus *Anopheles*, Order Diptera, Family Culicidæ.
[2] *Ædes ægypti* Linné, Order Diptera, Family Culicidæ.

The cause of the disease is an extremely minute organism, which has so far eluded all efforts to discover and isolate it. The unknown organism[1] is probably ultramicroscopic. While its transformations in man and the mosquito are not known, there is evidence that it passes an essential part of its life cycle in each host. The conquering of this disease constitutes one of the greatest triumphs of modern science.

Filariasis is caused by minute worms[2] that live in the blood and lymph. This disease is seldom fatal, but is often followed by terrible enlargements or deformities of the legs, arms, genital organs, or other parts of the body, known as "elephantiasis." The worms are found in the lungs and deeper blood vessels during the daytime, but when the patient is resting, usually during the night, these worms swarm into the superficial blood vessels, and mosquitoes feeding at this time may draw in some of them with the diseased blood. The worms undergo a transformation in the muscles of the mosquito, and 2 or 3 weeks later work out through the mouth parts as it is feeding on a new victim. Several kinds of mosquitoes[3] carry this disease. It occurs in many parts of the tropics.

The fourth disease of which mosquitoes are the known carriers is dengue or breakbone fever. It occurs in our southern states, but is more prevalent in the tropics. It is seldom fatal, but may attack practically the whole population of a village or community, so that temporarily great inconvenience and suffering are experienced. The symptoms are a very high, intermittent fever accompanied by terrible aches in the bones and joints. The cause of the disease has never been found and is believed to be an ultra-microscopic organism. It is spread chiefly by the bites of the common house mosquito of the tropics, also by the yellow-fever mosquito.

Animals Attacked.—While the diseases just discussed are known to be troublesome only in man, mosquitoes bite all kinds of domestic and wild animals, and doubtless transmit diseases to them (*e.g.* bird malaria).

Distribution.—While yellow fever has been nearly stamped out, the mosquito which carried this disease is still common in the southern part of the United States and the tropics. Other mosquitoes range from the equator nearly to the poles and from sea level to at least 7,000 feet altitude.

Life History, Appearance, and Habits.—Since there are more than 350 kinds of mosquitoes in North America, we shall attempt to give only certain general features of their life cycle and habits. Many species of mosquitoes go through the winter in the egg stage. Some winter as adult, fertilized females in washrooms, cellars, outbuildings, hollow trees, and other shelters, where they are often seen hiding in fall and spring. Others

[1] *Leptospira icteroides* Noguchi, was described in 1919 as the pathogen.

[2] *Filaria bancrofti* Cobbold, Phylum Nemathelminthes, Class Nematoda, Family Filariidae.

[3] The most important one is *Culex quinquefasciatus* Say, the common house mosquito of the tropics.

survive the winter in the larva stage, either freezing up with the water or remaining dormant at the bottom of ponds and puddles. Mosquitoes always develop in water, and their eggs are laid on the water or in places where water is likely to accumulate, as on ice or snow or in dry depres-

FIG. 549.—Larva of a malarial mosquito, *Anopheles quadrimaculatus* (Say), in resting position at the surface of the water. About five times natural size. (*From U. S. D. A. Farmers' Bull.* 450.)

sions. The eggs of the common Culex mosquitoes are built in minute rafts that look like a bit of soot floating on the water but are really composed of several hundred eggs standing on end. The eggs of malarial mosquitoes and yellow-fever mosquitoes are laid singly, the former

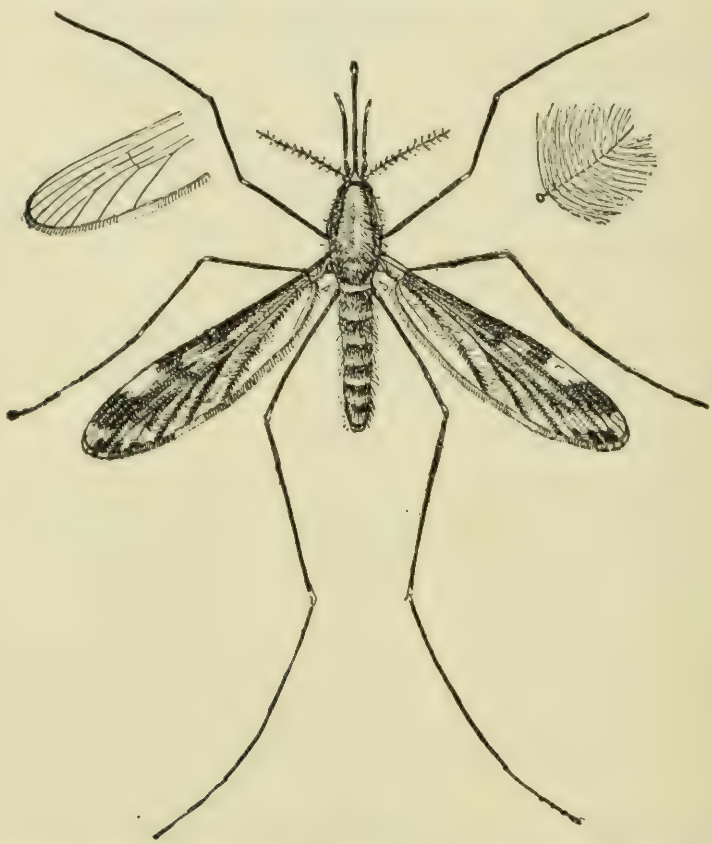


FIG. 550.—Female malarial mosquito, *Anopheles punctipennis* (Say), about four times natural size. Antenna of male at right, wing with scales removed to show venation, at left. (*From Fernald, "Applied Entomology."*)

having curious hollow expansions at the middle like a life belt, that keep them floating (Fig. 548).

The larvæ of mosquitoes (Figs. 548 and 549) are the common "wrigglers" of rain barrels and quiet pools. The head is large, and has complex mouth brushes that, constantly in motion, waft food into the mouth.

The mouth parts are of the chewing type, and they feed on algæ and other small plant or animal life either living or dead. The thorax is swollen and appears as one segment, but has no trace of legs in this stage. The abdomen is slenderer and bears on the eighth or next-to-last segment a short tube, known as a siphon, which the larva must thrust up into the air at intervals to breathe. This supply of air is supplemented by four finger-like, tracheal gills attached to the last segment on the body, by which oxygen is taken from that dissolved in water. The gills alone will not keep the larvæ alive, and they must come often to the surface to breathe. Indeed, they usually lie with the siphon projecting up through the surface film and the rest of the body hanging down at an angle in the water. In the larvæ of malarial mosquitoes, the siphon is very short and the larvæ generally lie parallel to the surface just below the surface film. When disturbed they swim down into the water by lashing the abdomen from side to side.

In as short a time as 2 days to 2 weeks, the larvæ may be full-grown, about $\frac{3}{8}$ inch long in common species. The change to the pupa stage takes place quickly at the fourth molt. This is a very unusual kind of a pupa (Fig. 548). It swims about actively in the water, avoids enemies, and does nearly everything the larva does except to feed. It breathes through two trumpet-like tubes on the thorax. The eyes, legs, and wings can be seen developing through the body wall on the large combined head and thorax. The pupa stage is often called a "tumbler." After a few hours to a few weeks in this condition, the insect splits its skin down the back and the adult (Fig. 550) crawls out, balances for a few moments on the empty pupal shell until its wings spread and dry, and then flies away. Most species pass through a number of generations each year.

The larvæ and pupæ of many common species breed in stagnant water of large or small quantity—anything from a bit of rainwater, caught in a discarded tin can, to the acres and acres of marsh water along our coasts and streams. The larvæ of malarial mosquitoes breed in a great variety of situations, including especially slowly moving or standing water in which green algæ abound. The yellow-fever mosquito breeds especially in and about dwellings and in cities wherever a bit of water, clean or foul, is left exposed long enough for it to complete its aquatic cycle. The adult of this species bites chiefly in the late afternoon and early morning. It is stealthy, does not make a very loud hum, is fond of crawling up under the clothing to bite, and prefers to stay in dwellings and other buildings. It has a peculiar, white, lyre-like pattern on the thorax. The malarial mosquitoes bite chiefly in the evening and early morning. Many of them can be distinguished from non-malarial kinds by the white-and-black or rusty-red spotting of the wings. The females also differ in having the palps about as long as the labium, whereas other mosquitoes have the palps, in the female, not over a third or fourth as long as the other mouth

parts. When biting or resting, the long axis of the body in the malarial mosquitoes is at an angle to the surface on which they are standing, while the common Culex mosquitoes hold the body parallel to the surface. Other kinds of mosquitoes bite mostly at night, but there are enough that venture forth in daytime in most sections to make life uncomfortable at any hour of the day or night, especially in the woods or about lowlands.

Control Measures.—Since no mosquito can come into its winged existence without water in which to grow, the best control is the removal of excess standing water by draining swamps, pools, and open ditches, by doing away with trash and all useless receptacles which may hold water, and by seeing that water does not stand in roof- or street-gutters, catch basins, and drains. Water which cannot be drained may be rendered mosquito-free by applying a thin film of oil to the surface, using about 1 pint (preferably a light fuel oil or half kerosene and half crude oil) to each 250 square feet of surface every 12 days. The malarial mosquitoes (only) may be killed by dusting Paris green (or crude sodium arsenite) over the water, using about 2 level teaspoonfuls of Paris green in 100 times as much fine dry dust for each 1,000 square feet of surface. It may be distributed by hand or, for large areas and impenetrable swamps, from airplanes.

The introduction of top-feeding minnows, goldfish, and other kinds of fish which feed on the larvæ is a practicable control in ponds or slow streams where the aquatic plants or shallowness of the water does not keep them away from the margins. The complete and careful screening of houses or beds is essential to comfort and health in most parts of the world. Mosquitoes may be cleaned out of a house by the use of certain commercial oil, pyrethrum sprays, or by generating hydrocyanic-acid gas, or burning sulfur as a fumigant (see pp. 255, 259). When one must be exposed to mosquitoes, gloves, veils, and leggings give a partial protection, as does the application of a repellent oil. Of the many mixtures recommended for this purpose, oil of citronella alone or mixed with equal parts of spirits of camphor and half as much oil of cedar is probably as good as anything. The addition of oil of tar makes the repellents stick longer on the skin.

References.—"*The Mosquitoes of North and Central America and the West Indies,*" 4 Vols. The Carnegie Inst. of Washington, 1912; *U. S. Dept. Agr. Bur. Entomol. Bull.* 88, 1910; *U. S. Dept. Agr. Farmers' Bull.* 1354, 1923; *N. J. Agr. Exp. Sta. Bulls.* 276, 1915 and 348, 1921.

Black Flies, Buffalo Gnats, or Turkey Gnats[1]

Importance and Type of Injury.—Small, clear-winged, humpbacked gnats (Fig. 551), hover about the eyes, ears, nostrils, and other parts of the body, making little noise but promptly alighting and sucking blood through their short, sharp mouth parts. They often appear in great

[1] Various species of *Simulium* and related genera, Order Diptera, Family Simuliidæ.

numbers and may be drawn into the air passages of animals, as poultry and large animals are apparently sometimes smothered by the swarms of flies. The bites are very irritating, and in many sections of our northern states and Canada, these little blood-sucking gnats make life unendurable for a definite season, mostly in spring. They bite especially about the face and neck but also on arms and any other part of the body that is exposed, and do not hesitate to crawl under the clothing to attack. The bites are not especially painful when made, but become increasingly itching, swollen, and irritating for some days. Black flies were, at one time suspected of being carriers of the human disease, pellagra, but this has been disproved.

Animals Attacked.—All warm-blooded animals.

Distribution.—Some species occur in nearly all parts of the United States and Canada. Especially troublesome in the northern woods and mountains.

Life History, Appearance, and Habits.—There are many species of black flies which differ considerably in life cycle. They generally winter as maggots below the water surface in swift, rocky streams, and the adult flies in many sections are most abundant in spring. The adults are from 1/25 to 1/5 inch long, with broad clear wings and sooty black, chunky body from the front end of which the head hangs downward, giving them a curious humpbacked appearance.

FIG. 551.—Adult buffalo gnat, *Prosimulium pecuarum* (Riley), about five times natural size. (*From Ill. State Nat. Hist. Sur., after H. Garman.*)

The eggs are deposited on the surface of rocks in swiftly flowing streams or attached to the leaves or stems of trees or plants so near the water that the weight of many eggs laid by a number of females may submerge them. On rocks they often form large, slime-covered patches, at first yellowish, changing to black. Within a week to a month the eggs hatch, and the curious yellow, brown, or black larvæ attach to the surface of rocks or loop about by means of suckers, fore and aft, and also by clinging to silken threads which they fasten to the rocks. Often they make conspicuous black moss-like patches, several feet across in the shallow water of rapids and at the brink of waterfalls. If such patches are examined in detail they are seen to consist of thousands of larvæ attached by their posterior ends, standing erect in the water with a pair of palmate brushes on the head fanning food-laden water into the mouth. The food is minute plant and animal life such as algæ, protozoa, and diatoms. The larvæ are therefore entirely harmless creatures that develop in streams often far from human habitations. After a month or so in this stage, or in some species not until the following spring, growth is completed and the larva makes a kind of open-end, silken cocoon attached to the rock, in which the pupa sits with its breathing tubes or tracheal

gills floating freely in the water. One to three weeks later the adults emerge, float to the surface of the water, and quickly take wing before being drowned in the current. Simultaneously with their emergence from the pupæ they change from harmless aquatic curiosities to bloodthirsty plagues (Fig. 551), that seek warm-blooded animals of all kinds, pierce the skin and draw the blood, leaving at the same time an irritating venom that causes extreme pain. It is only the females that suck blood. Sometimes black flies appear in sections remote from swift, rocky streams. This may be due to migration (aided by winds) from a considerable distance, but it must be remembered that there are many species of these flies and the life habits of most of them are imperfectly known. Whereas their favorite breeding grounds are the ripples of swift streams, some kinds must develop in large streams, ditches, and other slowly moving water.

Control Measures.—When one must venture into territory preoccupied by these gnats, the clothing should be securely closed at boot tops and wrists, and gloves and head veils worn if possible. Repellents such as recommended for mosquitoes are also of some importance, but must be applied frequently. One of the most important measures for the protection of live stock is to provide smudges in the fields or before the doors of barns or poultry houses by burning bark, moist punky wood, old leather, or green grass. The flies will not attack in the smoke. Repellent oils or sprays such as recommended for the horn fly are of only temporary value.

It is extremely difficult to destroy them in their breeding grounds. The application of a few gallons of phinotas oil to a small stream will kill the larvæ and pupæ down stream for many rods but it also kills the fish. Cleaning and deepening channels to remove logs, roots, stones, and other obstructions that cause ripples and waterfalls helps to reduce the numbers of these flies.

References.—*U. S. Dept. Agr. Bur. Ent. Bull.* 5, n. s., 1896; *U. S. Dept. Agr. Dept. Bull.* 329, 1916; *U. S. Dept. Agr. Bur. Entomol. Tech. Ser. Bull.* 26, 1914.

Punkies or No-see-ums[1]

These blood-sucking midges (Fig. 552) are not uniformly distributed, but occur locally in numbers sufficient to make them almost intolerable. They bite chiefly very early in the morning and at dusk. In some species the bite is very burning and painful and the victim is likely to be astonished when he notes the extremely small size of the creature that inflicted it.

Life History, Appearance, and Habits.—Punkies are very small, two-winged midges, commonly $\frac{1}{10}$ the length of a mosquito, the wings hairy and sometimes pictured but never with flattened scales. Two long veins near the front of the wings are distinct, the others very faint. The mouth parts are short, the body moderately heavy, and the legs rather stout. The larvæ develop in fresh or rarely in salt water, in ponds and

[1] *Culicoides* spp. Order Diptera, Family Chironomidæ.

pools of a variety of kinds. They are very slender and have a small brown head and a tuft of hairs at the opposite end. They breathe by means of blood gills after the manner of fish. The pupa is said to float in the water breathing from above the surface film.

Control Measures.—The same as for mosquitoes.

Horseflies or Deer Flies[1]

Many of the horseflies do not attack man, but a number of species of banded-winged, smaller, deer flies descend upon him when he ventures into their haunts in woods or marshes. They fly threateningly about the head in wild circles and if not constantly warded off alight and sink their mouth blades into the exposed skin. The bite is instantly very painful and considerable blood is drawn. Horseflies are the known carriers of anthrax, which they may spread, if disturbed while feeding on a diseased animal or carcass, by biting another person or animal soon afterwards.

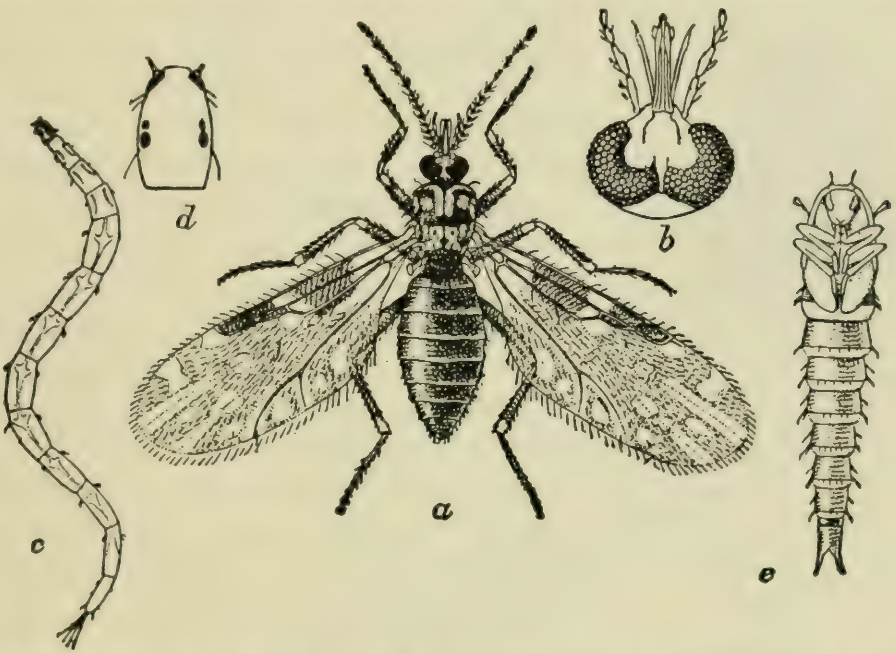


Fig. 552.—A punkie or no-see-um, *Culicoides guttipennis* (Coquillett). *a*, adult, fifteen times natural size; *b*, head of adult, more enlarged; *c*, larva; *d*, head of larva; *e*, pupa. (*From Riley and Johannsen, "Handbook of Medical Entomology," after Pratt. Courtesy Comstock Publishing Co.*)

Control Measures.—General measures are discussed under Horses (see p. 770). The same repellents recommended for mosquitoes are useful in preventing the bites of horseflies.

Stable Fly[2]

This insect, which has been fully discussed under Horses, commonly comes indoors or on porches, especially before a storm and bites people. It selects especially thinly clad ankles or exposed arms on which to feed. It is often called "the biting house fly," but should not be confused with the true house fly. The two species can be distinguished by the characters given in the key.

[1] *Chrysops* spp., Order Diptera, Family Tabanidæ.

[2] *Stomoxys calcitrans* Linné, Order Diptera, Family Muscidæ.

Bedbug[1]

Importance and Type of Injury.—The bite of a bedbug is not generally felt immediately, but the venom introduced soon causes itching, burning, and swelling to a variable degree, depending on individual susceptibility. On many people the bites become increasingly painful for a week or more. To many who live in refined homes and travel but little, the bedbug may seem a joke, but there are thousands who live in congested city districts, who never get a night's rest free from the attack of this loathsome pest. On account of the ease with which the insect is carried in baggage, hotel keepers find it one of their greatest plagues, and any one who travels extensively must expect to meet this bug frequently, not only in the cheap but also in the best of hotels and in sleeping cars. Under such conditions the bugs probably feed on different persons nearly every time they draw blood, and the conditions are very favorable for the spread of any blood-infesting disease organism. These insects have been suspected as carriers of leprosy, bubonic plague, oriental sore, relapsing fevers, and of a very fatal disease in India known as *kala azar;* but so far the proof that they are important in the transmission of any disease is not very conclusive.

Fig. 553.—A bedbug, *Cimex lectularius* Linné, eight times natural size. (*From Herrick, "Insects Injurious to the Household," copyright,* 1914, *by the Macmillan Company. Reprinted by permission.*)

Animals Attacked.—Besides feeding on man, the bedbug will attack mice, rabbits, guinea pigs, horses, cattle, and chickens when it is kept captive; and it may regularly feed on some of these in its natural surroundings.

Distribution.—The true bedbug is found all over North America, and is nearly cosmopolitan.

Life History, Appearance, and Habits.—In warmer regions and in rooms that are kept uniformly heated, the bedbug probably breeds throughout the year; in rooms where the temperature lowers perceptibly in winter it apparently winters chiefly as adults and nymphs, and egg laying is suspended until spring. The eggs may be found at any time during the warm months of the year. They are laid in cracks of furniture, behind baseboards, under loose edges of wall paper and all such crevices, where the adults hide during the day. They are elongate, whitish, big enough to be easily seen, and have a distinct lid at one end. Each female may lay from 75 to 200 eggs. The young bugs are similar to the adult when they hatch, but paler yellow in color. They molt five times, and

[1] *Cimex lectularius* Linné, Order Hemiptera, Family Cimicidæ.

at the last molt the abbreviated, useless, rudimentary wings appear and the insect is adult. Any one bug probably does not feed every night but, according to Marlatt, at least once a week or once before each molt. They may become adult within a month or two after hatching, but ordinarily growth is much slower, and there are from one to four generations a year. They may live long periods (4 to 12 months) without food. They may also feed on mice and other animals than man, so that empty houses may remain infested for long periods. Both males and females live on blood alone.

Any very flat brown bug is likely to be mistaken for the bedbug. There are many species living under bark of trees[1] that look something like bedbugs, but do not bite, and there are several other species that live in the nests of birds and bats, sucking their blood. Many false notions about bedbugs are current because people do not distinguish these similar-looking insects. The true bedbug (Fig. 553) may be recognized by the very slender third and fourth segments of its antennæ (the second segment being shorter than the third), by its almost lunate-shaped thorax into which the head is sunken and by being covered with very short hairs.

Control Measures.—A house infested with bedbugs should be fumigated either with hydrocyanic acid gas, using 1 ounce of sodium cyanide, or the equivalent of calcium cyanide, to each 100 cubic feet of space (see p. 254); or by burning sulfur at the rate of 4 pounds to each 1,000 cubic feet (see p. 259); or should be superheated to 130° F., holding this temperature for 3 to 6 hours. If the bugs are believed to be localized in some piece of furniture, they may be killed by applying kerosene or gasoline very thoroughly to all the cracks. Mattresses, rugs, and upholstery can be effectively treated by steam cleaning. New and especially second-hand furniture, laundry, and similar articles delivered to the home should be watched that the bedbug be not introduced with them. If one is traveling extensively, it is advisable to carry a small bottle of pyrethrum powder to be sprinkled over the bed under the sheets if these pests are found or suspected in the room. This will usually keep them from attacking one for the single night.

Reference.—U. S. Dept. Agr. Farmers' Bull. 754, 1916.

Assassin Bugs or Kissing Bugs

Importance and Type of Injury.—The bites inflicted by the Mexican bedbugs or big bedbugs,[2] China bedbugs[3] and the so-called "kissing bugs" or blood-sucking cone-noses[4] are scarcely exceeded in severity by any other insect. They have been likened in effects to snake bites. The

[1] Flat bugs, Order Hemiptera, Family Aradidæ.

[2] *Triatoma sanguisuga* Leconte, Order Hemiptera, Family Reduviidæ.

[3] *Triatoma protracta* (Uhler), Order Hemiptera, Family Reduviidæ.

[4] *Opsicoetes personatus* (Linné) and *Melanolestes picipes* Herrick-Schaeffer.

pain is intense and usually affects a considerable part of the body; swelling generally follows; and in the worst cases faintness, vomiting, and other ill effects are experienced that may last weeks or even months. In Brazil a related species is the carrier of a highly fatal disease known as Chagas disease. These bites may be experienced when one picks up the bugs or when they fly against the face. In the South and Southwest, the "big bedbugs," mentioned above, are aggressive and come into houses and bite at night to secure a meal of blood. It is believed that

FIG. 554.—An assassin bug or "kissing bug," *Melanolestes picipes* Herrick-Schaeffer, male, about four times natural size. (*From Ill. State Nat. Hist. Sur.*)

many of the painful bites of which spiders are accused, are caused by these bugs.

Animals Attacked.—Man, domestic mammals, and poultry.

Life History, Appearance, and Habits.—The eggs of these bugs are mostly laid out-of-doors under stones, logs, or other shelter, or, in some species, on plants. The young bugs probably feed chiefly on other insects, but may attack warm-blooded animals. One species is known as the masked bedbug hunter because the nymph has a sticky secretion all over the body to which dust and lint adhere so that, as it crawls along the floor, it looks like a bit of lint being blown along. It is believed to catch bedbugs and suck the blood from them. So far as these species have been studied, it appears that they have but one generation a year, as a rule.

These bugs (Fig. 554) have the characteristics of the order Hemiptera. The head is long, somewhat conical, the prothorax narrows in front, the

wings cross over flat on the back and the edges of the abdomen are produced as thin flat plates at the sides of the wings. These plates are in some species marked with pink or red bars, though the general color is dark brown or black.

Control Measures.—No control is known except to screen the bugs out of houses and to be very careful about picking them up. If they alight on the face flip them off quickly and do not take hold of them.

Fleas

Importance and Type of Injury.—Everyone knows that fleas commonly infest dogs and cats, and many have experienced the painful irritating bites that result when they suck the blood of man. The bites are likely not to be felt immediately, but become increasingly irritating and sore for several days to a week or more afterward. Unlike lice and ticks which, having found a host cling to it for dear life, fleas shift from host to host and feed indifferently on several kinds of animals. The cat flea[1] is nearly as likely to be found on a dog or a man as on a cat, and the so-called human flea[2] has been taken from dogs, skunks, rats, mice, and deer. The rat flea and those of ground squirrels also bite man. This promiscuous-feeding habit makes possible the most serious injury that fleas inflict, namely the transmission of bubonic plague from man to man. This is not the only way that plague may be contracted, but in the great epidemics fleas have been the most important factor in the spread of the disease. Plague is a bacterial disease caused by *Bacillus pestis.* This organism causes a fatal disease in rats as well as in man. In man these bacilli rapidly increase in numbers in the blood, lungs, or lymph glands, and in the most prevalent form of the disease, swellings from the size of a golf ball to that of an orange appear on the body, especially about the groin and armpits. From 20 to 95 per cent of the cases terminate fatally. Unlike the mosquito-borne diseases, no essential part of the life cycle of the plague bacillus takes place in the body of the flea. At least nine different species of fleas may carry the disease.

Animals Attacked.—Man, hogs, dogs, cats, rabbits, rats, mice, and all other kinds of rodents and many other animals are bitten by fleas. Bubonic plague occurs in man, rats, mice, certain ground squirrels, and some other rodents.

Distribution.—Fleas, as a group, are cosmopolitan. Bubonic plague has been most serious in Asia, Europe, and Africa. In the fourteenth century a great epidemic swept the Old World during which it is estimated that about 25,000,000 people died of this disease. In 1900 to 1914, there were a number of cases in San Francisco, and in 1914 a mild outbreak of this disease occurred in New Orleans.

[1] *Ctenocephalus felis* (Bouché), Order Siphonaptera, Family Pulicidæ.

[2] *Pulex irritans* Linné, Order Siphonaptera, Family Pulicidæ.

Life History, Appearance, and Habits.—Fleas, like most of the parasites of the large animals, continue their activity and reproduction throughout the winter, but breeding and all life processes are somewhat slowed down by cold weather. Although the adults are the only stage most of us see, fleas pass through all of the stages of a complete metamorphosis. The eggs (Fig. 555, *b*) are deposited in either the dust, dirt, or bedding of the host, or laid while the female is on an animal. They are never glued fast to the hairs, and those laid on the host usually sift readily through the hairs to the ground. The eggs are white, relatively large, and only a few are laid at a time, though the total number may be several hundred. The length of the egg stage is given as 2 to 14 days. The young flea (Fig. 555, *c*) is a very slender whitish larva about 1 inch

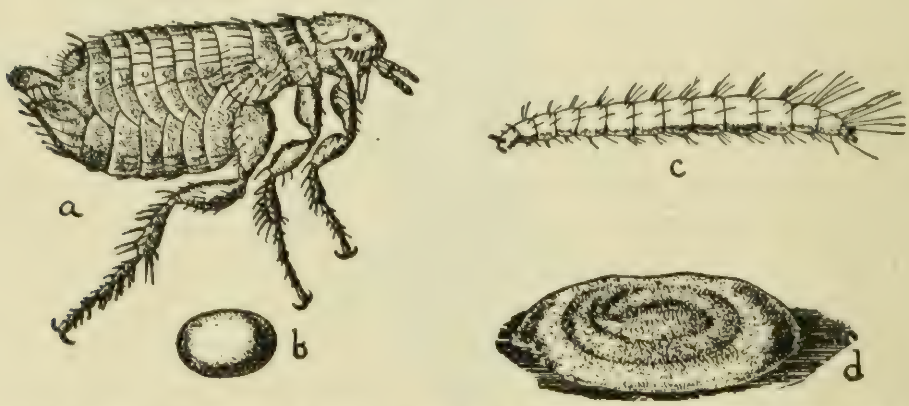


Fig. 555.—A flea. *a*, adult; *b*, egg; *c*, larva; *d*, cocoon. All much enlarged. (*From U. S. D. A.*)

long with a small brown head but without legs or eyes. The body is plainly segmented and is covered with scattered long hairs. The larva has chewing mouth parts and feeds on a variety of dry organic matter such as the excreta of the adult fleas or that of mice, rats, and other rodents. Larvæ can be reared successfully on the dirt scraped from the cracks of a wooden floor. The larval stage occupies from 1 to 5 weeks or more, and two molts have been recorded. However, since the larvæ generally eat their molted skins there may be additional instars that have not been observed.

When full-grown the larva forms a small oval cocoon of white silk to which adhere particles of dust and trash so as to give it a dirty, obscure appearance. From this cocoon (*d*) the flea emerges in 1 to 5 weeks although it may pass the winter in this way. Thus 2 or 3 weeks to 2 or 3 months are required for a generation of fleas of different species and under varied conditions. It thus happens that a house or basement in which cats or dogs have been permitted may be closed during an absence of the occupants and found upon their return to be overrun with these pests, although all animals have been excluded for a considerable time.

Adult fleas, after having fed, have been kept alive for 50 to 100 days, without further food.

Control Measures.—The habits of fleas make it plain that either to rid an animal of the pests or to clean up infested premises, the control measures must be of two kinds: (1) treatment of any cats, dogs, hogs, or other infested animals, to kill the adults on them; and (2) thorough and vigorous treatment of the kennels, pens, or sleeping quarters and even of the dry soil, dry manure and other litter in hog lots, under porches and in or under buildings to which the infested animals have had access.

The best treatment of pets is a thorough bath in warm water to which has been added from 2 to 4 tablespoonfuls of creolin to each gallon; or certain miscible oils or creosote dips. The head as well as other parts of the body must be wetted, by dipping it under and quickly rinsing the eyes with clean water. After 10 or 15 minutes, during which the animal must be prevented from licking its coat, the creolin is washed out with warm water and soap, and the animal allowed to dry its skin in a warm place. If bathing in this manner cannot be performed, dry powdered derris or pyrethrum may be sifted into the fur. This should be done over a box or paper and the fleas which drop from the animal should be burned to prevent their recovery. For hogs the methods recommended for hog lice (p. 799) are effective.

Houses or basements in which fleas are established should be fumigated with hydrocyanic acid gas (see p. 254); or by burning sulfur (see p. 259); or by closing the rooms tightly, one after another, and sprinkling over the floor about 5 pounds of flake naphthalene for an ordinary-sized room, closing it tightly for 24 hours, then sweeping up the remaining crystals and adding enough more to treat the next room. After such treatment the floors should be thoroughly scrubbed with hot soapsuds to kill the eggs, or with an oil mop wet in kerosene. Especial attention must be given to places where pets sleep. It should be realized that cats and dogs cannot be allowed regular access to the house without starting an infestation of fleas sooner or later, unless they are treated at regular intervals to a bath of creolin or one of the flea soaps. Where fleas have become established about barns, hog lots, and outbuildings, the infestation may be cleaned up by removing the manure and litter and spreading it in the fields at some distance from buildings and covering the ground in and around the infested buildings with a layer of salt, or spraying thoroughly with creosote oil, or applying calcium cyanide dusts.

References.—*U. S. Dept. Agr. Dept. Bull.* 248, 1915; *U. S. Dept. Agr. Farmers' Bull.* 897, 1917.

Chigoe Flea[1]

Importance and Type of Injury.—In the southern part of the United States, the West Indies, and other tropical regions, a small reddish-brown flea, about $1/25$ inch

[1] *Dermatophilus penetrans* Linné, Order Siphonaptera, Family Sarcopsyllidæ.

long, has the despicable habit of burrowing into the skin, especially between the toes and under the toenails. It causes much pain and itching, and as the female enlarges beneath the skin a pus-filled ulcer is formed. The sore is very likely to become infected with bacteria, and the entire toe, foot, or limb may be lost by blood poisoning. This insect must not be confused with the chigger mites, since both are called chiggers.

Animals Attacked.—Man, hogs, and other domestic animals.

Life Cycle, Appearance, and Habits.—Chigoes, like other fleas, develop in the soil or in filth, through a slender larval stage and a pupal period spent in a cocoon. When they become adult they attach to warm-blooded animals and suck blood. After mating, the female works her way into the skin, and her body becomes enormously enlarged, as her eggs develop, until she may be as large as a small pea. The eggs are generally extruded through the entrance hole and drop to the ground, where they develop to adults in about 1 month.

Control Measures.—Infested sores should be opened with sterile instruments, the fleas removed, and the wound given an antiseptic dressing. Shoes or boots should always be worn in the infested territory.

Spotted-fever Tick[1] and Other Ticks

Importance and Type of Injury.—Several kinds of eight-legged ticks attach to the skin of man and draw blood for days at a time. The dog tick,[2] the lone-star tick,[3] the castor-bean tick[4] and others are commonly found attached securely to the skin of children, hunters, and other persons who are much out-of-doors, especially in wooded places. The bites are not felt at the time the tick attaches, but cause more or less inflammation later. If the tick is forcibly removed, its mouth parts usually remain in the skin and cause an ulcer that is in danger of bacterial infection and serious complications. Another somewhat mysterious injury caused by ticks is a paralysis of the motor nerves affecting first the legs, and a few days later the arms, and gradually spreading, if not checked, until death may result. This disease, which is known as tick paralysis, results apparently only when the tick attaches at the back of the neck or base of the skull and does not begin until the tick has been feeding for about a week. The careful removal of the tick usually results in a speedy recovery. It is believed to be due to a poisonous substance introduced by the mouth parts of the tick.

The most serious injury to man by ticks is their known transmission of Rocky Mountain spotted fever. This is a highly fatal, continuous fever that begins a few days to a week after the attachment of an infected tick to the skin and often results in death within 2 weeks. Grayish or brownish spots usually appear on the arms, legs, and other parts of the body a few days after the fever begins. It is an interesting fact that while the fatality in the Bitter Root Valley of Montana runs about 70

[1] *Dermacentor venustus* Banks = *Dermacentor andersoni* Stiles, Order Acarina, Family Ixodidæ.

[2] *Dermacentor electus* Koch.

[3] *Amblyomma americanum* (Linné).

[4] *Ixodes ricinus* (Linné).

per cent, in the states to the south and west of Montana the mortality is less than 15 per cent. The cause of this disease, like that of yellow fever, successfully eluded man's most scrutinizing search for a number of years. It has probably been found by Wolbach, who gave it the name *Dermacentroxenus rickettsi*,[1] the latter part of the name a tribute to Dr. Howard T. Ricketts, who, with several other investigators, sacrificed his life in advancing our knowledge of this disease.

Animals Attacked.—Spotted fever affects man and many kinds of rodents. Tick paralysis has been noted only in man and sheep, although it has been produced experimentally also in dogs, rabbits, and guinea pigs. The spotted-fever tick feeds in its nymphal stages upon small wild animals, mostly rodents, such as ground squirrels, wood chucks, rabbits, rats, and mice, and when adult upon large animals such as men, dogs, horses, cows, mules, sheep, deer, mountain goats, and many others.

Distribution.—Some ticks are to be found in every section of the country. The spotted-fever tick occurs in the eight or nine states centering around southern Idaho, and the disease has occurred in all of these western states, except Arizona and New Mexico. Tick paralysis is reported from Montana, Oregon, and British Columbia.

Life History, Appearance, and Habits.—The life cycles of the several species that attach to man are in a general way similar. The seasonal cycles are very complicated and we shall indicate only the more important features for the spotted-fever tick.

There are four life stages: the egg, two nymphal instars (the first also called the larva, or seed tick), and the adult. The last three of these feed on the bodies of animals. Only the adults feed on man. The nymphs feed on small wild animals, especially rodents. Each stage remains attached to one spot on its host for from 1 to 2 weeks, then drops off and undergoes a period of resting, digesting, and molting on the ground, that may occupy a week or two or may extend over the entire winter. Each individual tick during its lifetime, therefore, requires three hosts, which are probably always different individuals and commonly three different species of animals.

The winter is passed as unfed males and females, and also as nymphs, either fed or unfed, among the grass and leaves. The adults (Fig. 556) feed only during the spring months, from about the middle of March to the middle of July; and this is the period when man contracts spotted fever. They climb up on brush and attach to any passing object. If this is a man, horse, cow, or other acceptable host they insert their mouth parts and draw blood for the next week or two. During this time the males visit the females, mating occurs and, when fully engorged, the female drops off of its host. During the next month she normally deposits about 4,000 small brown eggs, all in one mass under stones and

[1] Wolbach, S. B., *Jour. Med. Res.*, Vol. 41, No. 1, pp. 1–197, 1919.

other trash on the ground. The eggs hatch in from 2 weeks to nearly 2 months. The first stage nymphs (larvæ) have only six legs and are smaller than pinheads. They climb up on grass or other objects, and the fortunate few that are brushed off by some small wild animal may suck its blood during the first instar, then drop off the host and molt, find a new host, feed as second-stage nymphs, drop off, molt a second time, and winter either as adults or as second-stage nymphs and either before or after engorging. Others, from late-laid eggs, do not develop beyond the

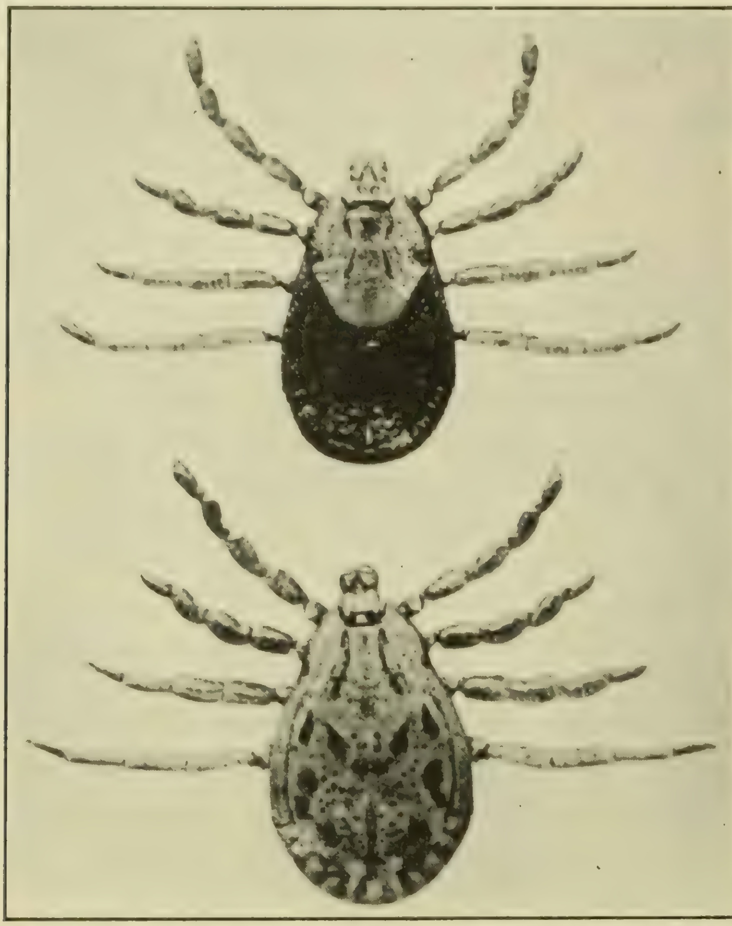


FIG. 556.—The spotted fever tick, *Dermacentor venustus* Banks. Adult unengorged female, above; adult male, below. About five times natural size. (*From U. S. D. A. Bur. of Ent. Bull.* 105.)

first stage nymphs, which mostly perish when cold weather comes, but may survive the winter. Those which winter as first- or second-stage nymphs may become adult the following summer, but, according to Bishopp and King,[1] these adults must pass another winter before they lay eggs.

The stages thus become very much mixed up, and eggs, small and large nymphs and adults can be found any time during the summer and the last two stages any time during the winter.

Two, three, or four years may be occupied in completing a generation, two years being the most common duration. The nymphs of the spotted-

[1] BISHOPP, F. C. and W. V. KING, *Jour. Econ. Entomol.* Vol. 6, No. 2, 1913.

fever tick are bluish-gray in color, the second stage easily distinguished from the first by its larger size ($\frac{1}{16}$ to $\frac{1}{6}$ inch long) and its additional pair of legs. The adults of the two sexes are different in appearance. The females are reddish brown, with a white shield covering the anterior half of the body. In the males the shield covers the entire back and has a pattern of white and brown stripes and dashes. Before feeding, the males and females are about $\frac{1}{16}$ inch long, but when fully engorged and ready to lay eggs the female is much larger, $\frac{1}{2}$ inch long by $\frac{1}{3}$ inch wide.

Control Measures.—When ticks are discovered on the human body, they should not be pulled off. A few drops of gasoline, turpentine, or creoline should be applied to them, which will cause them to release in a few minutes. The spot should then be disinfected with tincture of iodine, lysol, or weak carbolic acid.

The very complicated life cycle of the spotted-fever tick and the wild nature of much of the infested territory make control extremely difficult. The control of spotted fever is being carried out by dipping horses, cattle, sheep, and dogs during the spring months as described for the Texas-fever tick (see p. 791); by restricting grazing of domestic animals to starve out the adults; by repellent oils applied to grazing animals to keep off the ticks; and by poisoning and otherwise destroying the small rodents which serve as hosts for the nymphs, thus starving the latter.

References.—*U. S. Dept. Agr. Bur. Ento. Bull.* 105, 1911; *Mon. State Bd. Entomol. Fourth and Fifth Biennial Repts.*, 1919–1923.

Mites

A number of species of mites are troublesome to man, among them being the chigger or jigger (not to be confused with the chigoe flea, see p. 841), harvest mites, louse-like mites, and flour and meal mites. Mites are close relatives of ticks and spiders, and are not true insects. They represent distinct families of the class Arachnida and order Acarina, the larger ones of which are called ticks and the smaller ones mites

Chiggers, Jiggers, or Red Bugs[1]

Importance and Type of Injury.—From 12 to 24 hours after one has been on an outing in summer or autumn, particularly to spots where tall grass, weeds, and brambles abound, the skin may become inflamed in spots, especially where the clothing closely pressed the skin. Scattered red blotches of varied size appear, accompanied by a most intense itching that may not subside for a week or more. Some persons become feverish, extremely nervous, and seriously disturbed by such infestations.

Animals Attacked.—Man, domestic animals, poultry, certain ground-nesting birds, various snakes, land turtles, rabbits, and possibly other rodents.

[1] *Trombicula* spp., Order Acarina, Family Trombidiidæ.

Distribution.—The distribution of chiggers is not uniform, and is somewhat peculiar. Some local areas are badly infested, while others apparently similar and not far distant are practically free. Ewing states that one species occurs in the northern and western states and another in the Atlantic States and in Iowa.

Life History, Appearance, and Habits.—The causes of this trouble are small nymphal mites, less than $1/150$ inch in diameter and hence almost invisible to the naked eye. According to Miller[1] at least one species of chigger,[2] spends the winter in earthen cells $1/2$ to 1 inch below ground in the adult stage. The following spring they come out of the ground and lay their eggs. The young, six-legged mites that hatch from the eggs normally live on land turtles or on snakes, under the overlapping scales of the back, according to Miller (*loc. cit.*), or on rabbits, according to Ewing,[3] and it is only these first-stage nymphs that attack man. These are rounded, oval, bright orange-yellow in color, and run very rapidly. When one walks through grass and underbrush, these young chiggers may swarm over the body for several hours but are not felt until they settle down and begin to feed (Fig. 557). They undoubtedly introduce a definite poison that causes the irritation. It has often been stated that chiggers burrow into the skin and suffer a speedy death as a penalty for trespassing upon man; but we are apparently to be deprived of this consolation, for Ewing[3] contends that they do not burrow beneath the skin but only insert the mouth parts, sometimes in a skin pore or hair follicle. When full-fed they drop off of man. According to Miller, the full-fed, first-stage nymphs fall from their hosts in late September in southern Ohio and go into the loose soil to pass the winter. After molting and spending 2 or 3 weeks as quiescent nymphs, they molt to the adult stage but remain in their earthen cells until spring. There is only one generation a year. Ewing states that about 10 months are spent in the adult stage. The adults do not attack man, but are predaceous on minute insects and other arthropods.

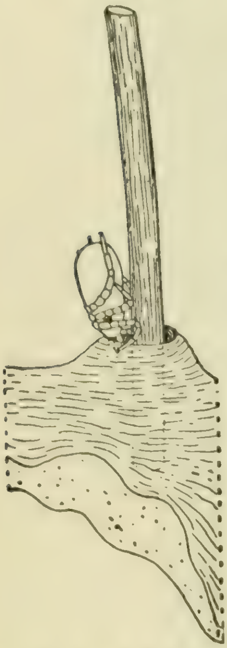


FIG. 557.—Chigger engorging, or feeding, at the base of a hair. (*From Ill. Agr. Exp. Sta. Circ.* 257, *after Ewing.*)

Control Measures.—If one anticipates a visit to the domains of these little tormentors, trouble may be prevented by dusting flowers of sulfur liberally and uniformly into the clothing. If this has not been done, or even if it has, a soapy bath within a few hours of the exposure, allowing the soap to dry on the skin, will usually prevent infection. After itching

[1] MILLER, A. E., *Science*, Vol. 61, No. 1578, pp. 345–346, Mar. 27, 1925.
[2] *Trombicula ilalzahuatl* Murray.
[3] EWING, H. E., *Science supplement* 2, Vol. 59, p. xiv, 1924.

begins, little can be done except to avoid infecting the bites by scratching. Some relief may be had by applying cooling ointments, such as salicylic acid in alcohol with a little olive oil. Premises infested with these mites may be freed by cutting out the underbrush, especially berry brambles, by keeping grass closely trimmed, by pasturing with sheep, and by dusting with sulfur at the rate of 50 pounds to the acre. Infested lawns have been cleaned of chiggers by dragging over them a piece of canvass or sacking wrung out of kerosene. The oil-soaked canvass should not be allowed to drip or remain long in one place, or the grass may be killed.

Reference.—U. S. Dept. Agr. Dept. Bull. 986, 1921.

Fig. 558.—Eruptions caused by bites of the harvest mite, *Pediculoides ventricosus* (Newport.) (*From U. S. D. A. Bur. Entom. Circ.* 118.)

Louse-like Mites or Harvest Mites[1]

Importance and Type of Injury.—Workmen while threshing wheat and other small grains, and occasionally people that sleep on straw-filled mattresses, may be overrun with microscopic mites that produce symptoms much like chiggers and are often called by that name. Within a day after exposure a hive-like eruption appears over much of the body (Fig. 558). These spots itch intolerably for several days to a week, and vomiting, headache, and fever may occur.

Animals Attacked.—Man and insects only, so far as known.

Distribution.—This mite has been most troublesome in the central, grain-growing states.

[1] *Pediculoides ventricosus* (Newport), Order Acarina, Family Pediculoididæ.

Life History, Appearance, and Habits.—This mite is usually predaceous on other insects, among which are the wheat jointworm and the Angoumois grain moth. Like the chiggers, they are practically microscopic, except that the female after mating becomes greatly enlarged with developing young so that her body, originally about $\frac{1}{125}$ inch long, then measures nearly $\frac{1}{16}$ inch. The young mites hatch from the eggs, and the nymphs develop to the adult condition within the abdomen of the female. They are then born ovoviviparously; they mate soon after birth, and within a week may have matured a second generation in the same manner. Each female may produce as many as 200 or 300 adult mites. The predaceous activities of the mites and their attacks on man, unlike that of chiggers, are therefore confined to the adult stage.

Control Measures.—The free use of sulfur dust among the clothing or the application of a greasy ointment to the body before working among infested straw, stubble, or seeds, followed by a soapy bath and change of clothes promptly afterward, should prevent any unpleasant results. Infested mattresses and other material may be cleaned by fumigation, by heating to at least 130° F. for several hours, or by steaming. After the irritation has begun, slight relief may be secured from the application of cooling ointments.

Reference.—U. S. Dept. Agr. Bur. Entomol. Circ. 118, 1910.

Flour and Meal Mites[1]

Trouble similar to that from chiggers and louse-mites is sometimes experienced by persons who work with flour, meal, sugar, dried fruits, cheese, hams, and the like, and is called "grocer's itch." This is caused by small mites (Fig. 507) that normally feed on these stored products (see p. 752), crawling upon the body and inserting their mouth parts.

They develop very rapidly under favorable conditions, and have a remarkable resting stage known as a *hypopus* that sometimes intervenes between nymphs and adults. In this stage the mouth parts are wanting, and there is a minute sucker on the under side of the body with which they attach to the bodies of such insects as occur in their feeding places, and probably to mice, and may thus be transported considerable distances and start a new infestation.

Control Measures.—When workmen are suffering from grocer's itch, the source of the mites should be found and the infested material or storeroom freed of them by fumigation, (see pp. 254 and 752) or by superheating (see p. 263).

Itch Mite[2]

Importance and Type of Injury.—The human itch mite (Fig. 525) is the same creature which, in horses and dogs, causes mange. There are several strains or varieties, each somewhat adapted to its particular host. The itch mite differs from the mites just discussed in spending its entire life cycle on the host. The eggs are laid in tunnels made by the burrowing

[1] Order Acarina, Family Tyroglíphidæ.

[2] *Sarcoptes scabiei hominis* (Hering), Order Acarina, Family Sarcoptidæ.

females beneath the skin (Fig. 9). Because of their internal position and very small size, the cause of itch was for centuries unknown, the trouble was attributed to improper living, immorality or "bad blood." Since no proper treatment was known, the mites multiplied for generations and years, on the body of their victim, thus giving rise to the expression "seven-year itch."

The newly mated females dig into the skin, making tunnels about $\frac{1}{50}$ inch in diameter and up to 1 inch in length. This burrowing, and more especially the feeding of the mites, cause the extreme itching that is the chief symptom of the disease. The tunnels are parallel with the surface of the skin and not very deep. They can often be seen as delicate gray thread lines beneath the skin, between the fingers and toes, behind the knee, on the external genitalia and, in prolonged cases, over most of the body except the head. Hard pimples about the size of pinheads containing a yellow fluid form over the affected skin, and as these are scratched usually become infected and cause large ugly sores and scabs. The nervous strain and the venom introduced by the feeding of the mites may greatly depress the individual and disturb the health.

Animals Attacked.—Man, dogs, rabbits and ferrets. Varieties of the same species cause mange of many other animals.

The life cycle and habits of the mites are given under mange mite of the horse (page 775).

Control Measures.—Since the mites crawl about over the body chiefly at night, infection usually occurs by occupying the same bed with one who has the itch. The use of the same towels or clothing with a victim may also spread the disease. Infected individuals should be isolated from the rest of the household as much as possible. Treatment consists in (1) thoroughly massaging the skin over the entire body except the head, with green soap and hot water, keeping this up for about 1 hour in order to soften the scabs and open the burrows of the mites; (2) the application, with prolonged rubbing in, of balsam of Peru, sulfur ointment, or, as recommended by Chandler,[1] a mixture of "beta-naphthol 75 grains, olive oil $2\frac{1}{2}$ fluid grams, sulfur 1 ounce, lanolin 1 ounce, and green soap 1 ounce;" (3) the sterilizing of the underwear, bed-clothing and towels used by a patient; (4) the repetition of the treatment in from 3 to 10 days, to destroy mites hatching from unkilled eggs.

Human Body Louse[2] and Head Louse[3]

Importance and Type of Injury.—Human lice, like the bedbug, are fortunately nothing but a loathsome thought to the vast majority of cleanly people. But to thousands of the world's less happily situated

[1] "*Animal Parasites and Human Disease*," John Wiley & Sons, 1918.

[2] *Pediculus humanus corporis* DeGeer, Order Anoplura, Family Pediculidæ.

[3] *Pediculus humanus capitis* DeGeer, Order Anoplura, Family Pediculidæ.

souls they are inseparable companions. In time of war, troops have always suffered unspeakably from these pests. During the Civil War they were known as "greybacks" but during the recent World War they became notorious under the name of "cooties." In times of peace, lice are largely confined to jails, prisons, laborer's camps, slums of cities, or other places where unsanitary living prevails. In the great melting pot of our public schools, lice may easily gain access to any child and so be introduced to any household. It is as well, therefore, to swallow our loathing, and learn enough about these parasites to enable us to help some unfortunate, if occasion arises, and to protect ourselves or our homes if chance or the stress of war should subject us to so unpleasant an experience.

All of the lice found on the body of man are of the blood-sucking kind,[1] no chewing lice[2] of man ever having been discovered. The bites of these lice, although scarcely felt at the time, are as irritating as those of fleas and bedbugs. Their crawling on the skin is also very annoying. Scratching is almost inevitable, and the skin becomes scarred, thickened, and bronze colored with brownish spots. A generally tired, "grippy" feeling, fever, and an irritable and pessimistic state of mind are attributed to the feeding of lice. The most serious injury, however, is the proved connection of the body louse with several human diseases, such as typhus fever, trench fever, and relapsing fevers. The most serious of these, and the only one so far occurring in America, is typhus fever. Typhus fever (not to be confused with typhoid) is a continuous fever accompanied by a spotted skin eruption that makes the disease seem very much like spotted fever. The mortality is ordinarily from 15 to 30 per cent, but under war conditions more often 50 to 70 per cent. There have been outbreaks in New York and Philadelphia, but the United States has never experienced a devastating epidemic of this disease such as occurred in Russia, 1905 to 1911, with 50,000 deaths; or in Serbia during 1915, when there were as high as 9,000 deaths a day and a total of 150,000 in that small country. The disease occurs every year in the higher and cooler parts of Mexico, and is in general a disease of cool climates and of winter weather. Typhus never occurs in the absence of lice, and may be acquired either by the bites of diseased lice or by crushing them upon the skin near the punctures they make or by scratching with finger nails infected with the body fluids of lice.

Animals Attacked.—This species lives only on the various races of men, except that it occasionally occurs on monkeys or apes in confinement.

Distribution.—Lice occur in all countries and upon all races of people. The body louse is less abundant in the tropics; probably due, as Nuttall

[1] Order Anoplura.

[2] Order Mallophaga.

suggests, to the lesser amount of clothing worn as well as to temperatures too high for them.

Life History, Appearance, and Habits.—Head lice and body lice are almost indistinguishable in appearance, but their habits are very distinct. They have usually been considered two different species; but since Bacot,[1] has shown that they produce fertile offspring when crossed, and Nuttall,[2] has shown that there are no constant morphological differences, and Keilin and Nuttall,[3] have shown that the head lice lose all their usual differences when reared for a few generations under conditions that the body louse normally experiences, we must consider that they are only races or varieties of one species.

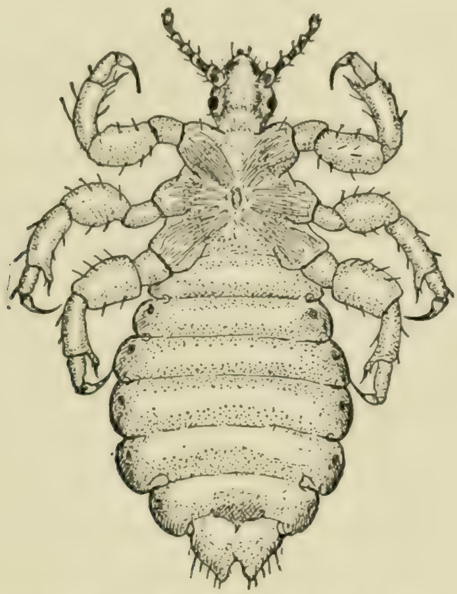


FIG. 559.—Human body louse, *Pediculus humanus* Linné. Under side, twenty times natural size. (*From Herrick's "Insects Injurious to the Household," copyright,* 1914, *by the Macmillan Company. Reprinted by permission.*)

Human lice (Fig. 559) are grayish, flattened, wingless, six-legged insects, $\frac{1}{12}$ to $\frac{1}{8}$ inch long by about one-third as wide, with short, five-segmented antennæ, simple eyes, rather heavy legs that terminate in a single, sharp, curved claw for grasping about hairs, and piercing mouth parts that, when not in use, disappear completely into the front of the head (see Fig. 68). The body louse is typically larger, lighter in color, with slightly longer antennæ, longer, more slender legs, and the constrictions between the abdominal segments less conspicuous than in the head louse. In spite of these differences it is usually difficult to tell from an isolated specimen which form it is. Normally, however, the habits are very distinct. The head louse lives *on the skin and among the hairs of the*

[1] BACOT, A., *Parasitology*, Vol. 9, pp. 228–258, 1917.

[2] NUTTALL, G. H. F., *Parasitology*, Vol. 11, Nos. 3, 4, pp. 329–346, 1919.

[3] KEILIN, D. and G. H. F. NUTTALL, *Parasitology*, Vol. 11, Nos. 3, 4, pp. 279–328, 1919.

head, while the body louse lives *in the clothing*, only going on to the skin to feed, and even then retaining its hold on the adjoining part of the clothing.

Both of these species occur associated with man the year around, but become most prevalent in winter or at any time when their victims crowd together in warm, poorly ventilated houses which furnish conditions best suited for the increase of lice. All stages may be found at any season of the year. The head louse lays its eggs chiefly glued to the hairs of the head, back of the ears, and at the back of the neck. The body louse is remarkable in being the only louse that lays its eggs among the seams of clothing, to the fibers of which they adhere. The eggs are elongate oval in outline, about $\frac{1}{25}$ inch long, with a distinct pebbled lid at one end and whitish in color. They hatch in about a week under favorable conditions, and the very tiny, slender lice at once begin feeding. They continue to feed from two to six or more times a day for the next 2, 3 or 4 weeks, growing meantime and molting three times before they become adult. The adults live for about 1 month more, the females laying an average of 8 to 10 eggs a day until a total of approximately 100 are deposited by the head louse and 200 or 300 by the body louse. Under conditions where the clothing is not, or cannot be, changed for long periods, the number of lice on one person may sometimes range from 1,000 to 10,000.

Control Measures.—On account of the abundance of lice in Europe during the World War, and their announced connection with the spread of typhus and trench fevers, the most extensive investigations were undertaken and hundreds of remedies and very elaborate plans for delousing troops were devised. For an excellent discussion of this subject, the reader is referred to the article by Nuttall.[1] In peace times most persons will be interested chiefly in methods of avoiding infestation by these revolting creatures and possibly in helping some unfortunate child or wretched tramp to get rid of an infestation.

The indiscriminate use of public combs, brushes, and towels, trying on of headwear, sleeping in infested rooms or sleeping cars, and all contact with unclean persons should be avoided. An infested head should be treated with equal parts of kerosene and olive oil and thoroughly shampooed an hour or two later with hot water and soap. Another treatment is to soak the hair for a quarter of an hour with a solution of 12 grains carbolic acid crystals in a pint of water, then wrap the wet hair in a cloth for an hour or so before washing out the solution with warm soapy water. Clipping the head and burning the hair will make control easier. A second treatment will not usually be necessary.

When the infestation is of body lice especial attention must be given to killing the lice and their eggs in the clothing. This may be accomplished by steam sterilization or by a dry heat of 140 to 160° F. for 20

[1] Nuttall, G. H. F., *Parasitology*, Vol. 10, No. 4, pp. 411–588, 1918.

minutes, or by fumigation with carbon bisulfide or carbon tetrachloride in a tight box. During this time the victim should take a thorough bath in hot water and soap, or the kerosene and olive oil mixture may be applied all over the body. Sleeping quarters of infested persons may be disinfected by live steam or by fumigating as for bedbugs. Zinc oxide ointment is soothing to the skin.

References.—Parasitology, Vol. 9, pp. 228–258, 1917; Vol. 10, pp. 411–588, 1918; and Vol. 11, pp. 279–346, 1919; *Research Publication, Univ. Minn.* Vol. 8, No. 4, July, 1919.

Pubic Louse or Crab Louse[1]

Importance and Type of Injury.—Although this species is very closely related to the head louse and body louse, it presents a very different appearance (Fig. 560), and its habits are quite distinct. It is almost entirely limited to the part of the body at the crotch of the legs and to the armpits, but rarely occurs among the eyelashes, eyebrows, and beard. Nuttall,[2] shows that the reach of the two extended legs of the louse corresponds closely to the distance apart of the coarse hairs in these places and concludes that this louse so seldom infests the head because the hairs there are finer and closely crowded together. Severe itching, especially in the hairy parts of the pubic region, accompanied by inflamed spots, is caused by the feeding of these small lice. When these spots are scratched, a more or less severe eczema may develop. According to Nuttall,[3] faint bluish-gray spots of varying size characteristically appear beneath the skin where these lice have fed. The same author finds that fever, headaches, and other disturbances may occasionally result from the poison introduced by the feeding of the lice. This louse is not known to transmit any disease.

Animals Attacked and Distribution.—Known to attack only the white and negro races of men and probably occurs wherever these races live. It has been taken from dogs.

Life History, Appearance, and Habits.—The eggs are attached to the coarse hairs of the body among which the lice feed. Nuttall,[1] thinks that as many as 50 eggs are laid by one female, although other authors record only about a dozen. The same author finds that the egg stage lasts about a week and the nymphs molt three times and are mature in 2 or 3 weeks after hatching. The full-grown louse is about $\frac{1}{16}$ inch long by about two-thirds as broad, but the legs sticking out at the sides give it a still broader appearance. It is grayish white in color with darker legs and shoulders. The general appearance of the louse is that of a minute gray speck which, when magnified, suggests a miniature crab. The legs

[1] *Phthirius pubis* (Linné), Order Anoplura, Family Pediculidæ.

[2] Nuttall, G. H. F., *Parasitology*, Vol. 10, No. 3, pp. 383–405, 1918.

[3] Nuttall, G. H. F., *Parasitology*, Vol. 10, No. 3, pp. 375–382, 1918.

are similar to those of the body louse except that those of the first pair lack the "thumb" against which the curved claw closes in the other legs. The margins of the abdomen have short, finger-like projections, the ends of which are provided with bristles.

Control Measures.—One should use care to avoid contamination with this pest in public toilet rooms, baths, and unclean rooming houses, and especially by close association with infested persons. Mercurial ointment is usually recommended. Herms advises a mixture of yellow oxide of mercury 10 parts, salicylic acid 1 part, and vaseline 89 parts, or the application of a 10 per cent solution of tincture of larkspur, repeated in 8

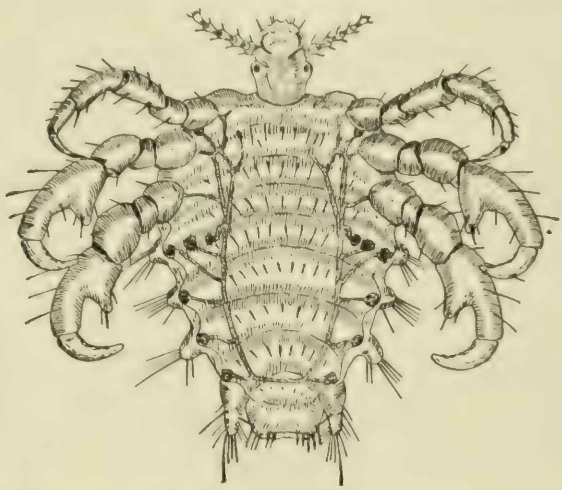


FIG. 560.—Crab louse, *Phthirius pubis* (Linné); underside, about twenty times natural size. (*From Herrick's "Insects Injurious to the Household," Copyright,* 1914, *by the Macmillan Company. Reprinted by permission.*)

days, or the application of kerosene and vinegar followed by a bath in warm soapy water.

Reference.—Parasitology, Vol. 10, pp. 375–405, 1918.

Internal Insect Parasites

Importance and Type of Injury.—While there are in the tropics several species of maggots that live in the flesh of the human body, such as the Congo floor maggot,[1] the tumbu fly,[2] and the human bot fly,[3] myiasis (as the presence of fly maggots in the body is called) is really exceptional and accidental under normal conditions in temperate America.

About a dozen different species of flies have been recorded as occasionally infesting the human body in their larval stages. They occur in wounds, in the cavities leading from the mouth and nose, in the alimentary tract, and very rarely in the urinogenital passages. They reach these positions by being swallowed with water or food containing the eggs or young maggots, or the latter are deposited in wounds or body openings by the adult flies. In either case the larvæ of the species concerned find conditions such within the body that they can live for a long time and often until

[1] *Auchmeromyia luteola* Fabricius, Order Diptera, Family Muscidæ.

[2] *Cordylobia anthropophaga* Blanch., Order Diptera, Family Muscidæ.

[3] *Dermatobia cyaniventris* Mac Q., Order Diptera, Family Œstridæ.

full-grown. The results of the infection are apt to be very pronounced, and the condition is so offensive that it is likely to assume undue importance from the vivid accounts of the sporadic cases in medical literature.

The screw worm fly, which has already been discussed as a pest of cattle, sometimes attacks men, especially through the nostrils, with dreadful results. A flesh fly known as *Wohlfahrtia vigil* has been taken working under the skin. The little house fly,[1] has been recorded a number of times from the urinary tract especially of women. The largest number of cases is recorded from the intestines. These are caused by the little house fly, the latrine fly,[2] the pomace fly,[3] the house fly, several kinds of flesh flies and species of rat-tailed maggots.[4] The usual symptoms are nausea, vomiting, severe abdominal pains, a bloody diarrhœa, and sooner or later the passage of maggots with the excrement.

Control Measures.—Reasonable care about eating uncooked meats, vegetables, and fruits, or using poorly cleaned milk bottles, and the protection of the mouth, nostrils, and other body openings, especially in the case of children and others when they are afflicted with catarrh, bad breath, or otherwise unclean, is important in avoiding the attacks of these flies. The presence of fly larvæ in any part of the body should receive the immediate attention of a skilled physician to avoid serious injury and possibly a horrible death.

House Fly[5]

Since the discovery of the importance of the common house fly (Fig. 561) as a carrier of various diseases, a few decades ago, several entire books, and many special articles have been written about it. Only the more important points about the fly, that every citizen should understand are explained in the following account. For a more complete exposition of its revolting and dangerous habits and the details of its morphology, life cycle, and control the reader should refer to some of the special references.

Importance and Type of Injury.—The common house fly is the most dangerous animal living within the boundaries of many of our states. This in spite of the fact that it cannot bite or sting or otherwise *cause* disease *of itself* in any life stage. Its importance lies in the fact that it is the *carrier* of millions of bacteria and protozoa among which have been found the germs or pathogens of the following human diseases:

Typhoid fever	Whipworm
Diarrhœa	Asiatic cholera
Amœbic dysentery	Yaws
Tuberculosis	Ophthalmia
Anthrax	Erysipelas
Leprosy	Gonorrhœa
Tapeworms	Septicæmia
Hookworms	Abscesses
Round worm	Gangrene

[1] *Fannia canicularis* Linné, Order Diptera, Family Anthomyiidæ.
[2] *Fannia scalaris* Fabricius, Order Diptera, Family Anthomyiidæ.
[3] *Drosophila* spp., Order Diptera, Family Drosophilidæ.
[4] Several genera of Order Diptera, Family Syrphidæ.
[5] *Musca domestica* (Linné), Order Diptera, Family Muscidæ.

It must be understood that the house fly is not the sole transmitter of any of these diseases in the way that mosquitoes are related to malaria or lice to typhus. Practically all authorities are agreed, however, that the house fly is an important factor in the spread of diseases such as typhoid fever, epidemic or summer diarrhœa, dysenteries, and other bacterial infections of the stomach and intestines. There is also strong evidence that the fly may be a dangerous carrier of tuberculosis, anthrax, parasitic worms, and many other diseases. In all of these cases the germs of the diseases are picked up by the fly from human excrement, sputum, the carcasses of diseased animals, manure, and other filth, which the fly visits; or are taken up by the larvæ and remain in a living condition in its body during the pupal stage and may then be scattered about by the deposits from the body of the adult fly. That the hairy body of the house fly is an admirable carrier of bacteria is attested by Esten and Mason (as cited by Herms) who found an average of 1,250,000 bacteria on each of 414 flies examined, the maximum on a single fly being 6,600,000. The house fly carries disease germs either on the outside of the body clinging to its mouth parts, feet, wings, and other body surfaces, or in its alimentary canal, where they resist digestion and may remain in a living condition for many days. If carried externally they may be dropped or rubbed off or washed off by the fly, on foods, drinks, wounds, or the eyes or lips of man. If carried internally they are deposited either by regurgitation or in the feces ("fly specks") in such situations that they may be taken into the mouth or upon some delicate body surface like the eye or a sore, and start disease.

A minor but not unimportant injury from the house fly is as a nuisance about men and other animals where rest and sleep are disturbed by its ubiquitous buzzing and alighting on the skin.

Animals Attacked.—Man is not the only animal injured by the house fly. Although it does not bite, it annoys domestic animals by alighting on their bodies, and may even serve to transmit certain diseases by sipping blood from wounds made by other insects.

Distribution.—The house fly is practically cosmopolitan and is the commonest fly found in houses throughout most of the world. Explorers in parts of the earth rarely frequented by man have been greatly annoyed by the house fly.

Life History, Appearance, and Habits.—Entomologists are not in agreement as to how the house fly passes the winter. There is some reason to believe that it hibernates as an adult, but there is more evidence that it winters as larva or pupa, or both, beneath manure piles and in other breeding grounds. In heated buildings and in warmer parts of the earth it continues to breed slowly throughout the winter. The house fly combines a large family with one of the shortest life cycles known among insects. From 100 to 150 eggs (Fig. 561, *c*) are laid at a time,

and from two to seven such batches may be deposited by one female, so that a total of 500 eggs from one fly is probably a normal production. The record so far as known is 21 batches, or a total of 2,387 eggs, from one fly. The whole life cycle from egg to adult may be completed in from 6 to 20 days and a new generation started in from 2 to 20 days more. The length of the various stages under favorable conditions is somewhat as follows:

Egg	*Larva*	*Pupa*	*Adult to Eggs (Preoviposition Period)*
8 to 30 hours	5 to 14 days	3 to 10 days	2¼ to 23 days

Most house flies come from horse manure, as it is in this substance that they prefer to lay their whitish, elongate eggs, 25 of which end to

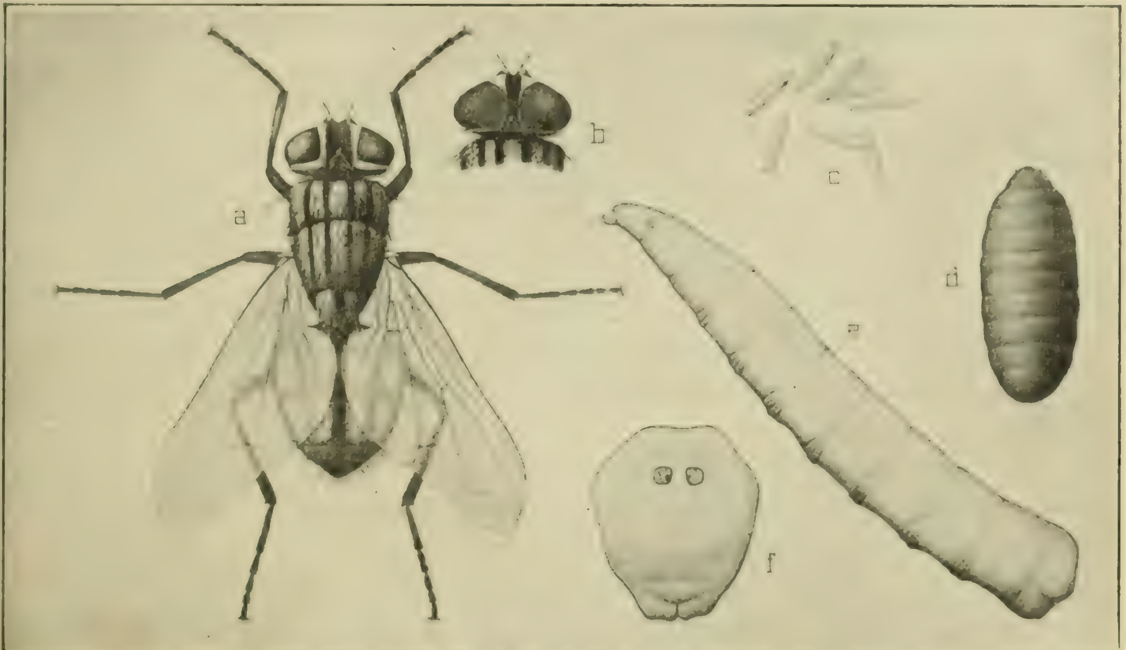


FIG. 561.—The house fly, *Musca domestica* (Linné); *a*, adult female, about five times natural size; *b*, head of male; *c*, eggs, about six times natural size; *d*, puparium, about four times natural size; *e*, larva or maggot, about seven times natural size; *f*, last segment of larva to show spiracles. (*From Ill. State Nat. His. Sur.*)

end reach 1 inch. A young house fly (Fig. 561, *e*) is not a miniature of its parents, but is the legless, footless, and almost headless, white maggot familiar to every boy who has cleaned the manure from stables. Feeding on this material or on the micro-organisms that cause it to ferment, the maggot reaches full growth in a few days, and then forms a seed-like, chestnut-colored puparium (*d*) of its third larval skin, within which the change to adult takes place. Before forming the puparium, the larva migrates to some drier part of the substance on which it fed. Every house fly thus passes a wingless egg, larval, and pupal existence in some fermenting material before it can appear in the familiar winged condition. While horse manure is preferred, they can develop in any moist, warm,

fermenting, organic matter ranging from piles of grass, decaying fruits or vegetables, garbage, and waste about feed troughs, to human and animal excrement of all kinds. While it was estimated a few years ago that 90 per cent of our flies develop in horse manure under average conditions, we may be sure that the complete extermination of the horse would not remove the house-fly pest from our midst.

Professor C. F. Hodge,[1] has made the following remarkable statement about the possible increase of house flies if all were to continue to reproduce at the normal rate:

> "A pair of flies beginning operations in April may be progenitors if all were to live, of 191,010,000,000,000,000,000 flies by August. Allowing ⅛ cubic inch to a fly, this number would cover the earth 47 feet deep."

Of course such increase never occurs, but this statement serves to show why flies increase so rapidly when summer comes.

Since the fly is injurious in the adult stage only, the question "How long does a fly live?" becomes of real importance. It is difficult to get adequate information on this point because under normal conditions no one fly can be kept under observation for even an hour, much less its whole lifetime; and if placed in confinement we do not know that the length of life is normal. In one series of experiments, the average adult life of 3,000 flies kept in cages was 19 days. Another investigator says that 30 days seems to be a normal lifetime. One fly was kept alive 70 days.

The thing above all else that makes the house fly such a dangerous messmate is its inordinate curiosity, which leads it to go everywhere and to feed on almost anything. From manure piles, sewage, garbage, sputum, and carcasses of animals to food of all kinds in dining room, kitchen, restaurant, and grocery and to the lips, eyes, and nursing bottles of sleeping children is "all in the day's work" for a busy house fly. If they stayed in filthy places or remained all of the time in our houses, the objection to them would not be so great. But their promiscuous habits result in polluting their bodies with filth and shedding it in their path, wherever they go.

It is interesting to note that the house fly's mouth parts (Fig. 70) are such that it can take in only liquid foods. Any solid substances on which it feeds are first dissolved in its own saliva and the solution then sponged up.

The point as to how far a house fly can fly becomes an important one when the question of control in restricted areas arises. In one experiment, 387,000 marked flies were released and 1,000 of them recovered at distances ranging from 50 yards to 2 miles from the starting point. In general it seems that few flies will range farther than is necessary to

[1] Hodge, C. F., in *Nature and Culture*, July, 1911.

secure food and a place to lay their eggs. When abundant in a city, it is fairly certain that they are breeding in the same or an adjoining block. Their roving habits, however, point to the necessity in general of community action to control them.

Vastly more careful study of the house fly, particularly exacting bacteriological studies of its relation to a host of diseases, is needed. Careful observation of characteristic habits may also be of genuine value. In order that these be not misleading, it is essential that the observer *know* the species with which he is working. It must not be assumed that any fly caught in a house is the house fly. Only a checking by *all* of the characteristics given in the key (p. 826) will determine it certainly.

Control Measures.—The presence of house flies means that our sanitation is defective. Failure properly to dispose of manure, garbage, sewage, food wastes, human excreta, dead animals, and other organic waste materials is the only thing that will account for an abundance of these insects. Stables built with concrete floors, properly constructed to prevent liquid manure from leaching into them and to make it possible to clean them thoroughly by washing down every day is the first step in control under farm conditions. Manure removed from stables should be immediately carted away and scattered thinly over fields. Manure is never so valuable as when perfectly fresh. The common practice of storing manure in the barnyard, results in a loss of from 25 to 65 per cent of its fertilizing value in 6 months time, due to leaching and hot fermentation. But more important is the fact that flies cannot breed in the thinly scattered material, due to drying out and absence of fermentation. A half-ton manure pile, after being exposed for only 4 days, was found to contain (estimated) over 400,000 fly larvæ, or 400 larvæ to the pound of fresh manure.[1] After manure is well rotted, flies are not attracted to it to lay their eggs. If daily scattering of manure cannot be practiced, the maggot trap may be used to destroy most of the maggots, without depreciation of the fertilizing value of the manure. The maggot trap is a slatted platform about 10 by 20 feet in size, supported within and over a shallow cement vat. The manure is removed from the stable each day and dumped upon this platform. It is kept wet by pumping water over it from a cistern adjoining the vat, into which the water from the vat can be drained at intervals. A few inches of water are kept in the vat all of the time. Under such circumstances, fly larvæ grow in the manure to full size. Then, driven by a negative hydrotropism to seek a dry place before pupating, they desert the manure if it is kept wet, fall through the slats and are drowned in the water. If manure must be allowed to accumulate in the stable or barnyard it should be treated chemically to destroy the eggs and larvæ. Considering the factors of safety about the premises, non-injury to the legs of animals, high toxicity

[1] Herms, "Medical and Veterinary Entomology," p. 209, 1923.

to fly larvæ, and safety to plants on soil where it is applied, *borax* appears to be best for this purpose and 1½ ounces of borax dissolved in 2½ gallons of water should be sprinkled over the manure from each horse each day so as to wet all parts of it. Borax costs about 10 cents a pound. Materials therefore cost about 1 cent per horse per day for such treatment.[1]

In addition to these control measures which go to the heart of the problem and get the fly before it reaches the dangerous winged condition, some help may be secured by the use of traps. Various home-made kinds are described in *U. S. Dept. of Agr., Farmers' Bull.* 734. Bananas and milk or brown sugar and cheese, equal parts, kept wet and fermenting, make attractive baits for traps. As repellents, the electric fan over entrances; creosote oil about stables; and a mixture of coal tar, 3 parts, and carbon bisulfide, 1 part, kept stoppered and applied with a brush to wounds of animals, may be found useful. A house which has become filled with flies may be most easily cleaned of them by puffing 2 or 3 ounces of pyrethrum powder, or various commercial preparations, into the air of each ordinary-sized room and closing it tightly for ½ hour. At the end of this time the stupefied flies may be swept off the floor and burned.

The control of the house fly presents no greater difficulties than that of the southern cattle tick, the codling moth, or other widespread and abundant pests. It can and will be controlled when the general public becomes educated to view it as the real menace to health that scientists know it to be.

References.—Among the most important are Howard, L. O., *The House Fly, Disease Carrier*, Frederick A. Stokes Company, 1911; Hewitt, C. Gordon, *The House Fly; A Study of its Structure, Development, Bionomics* and *Economy*, Manchester University Press, 1910; Graham-Smith, *Flies and Disease: Non-blood-sucking Flies*, Cambridge University Press, 1914; *U. S. Dept. Agr. Farmers' Bulls.* 679, 1915; and 1408, 1924.

[1] See *U. S. Dept. Agr. Dept. Bulls.*, 118, 1914; 245, 1915; and 408, 1916.

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